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UCRL-ID-122665
L-20590-1

Fissile Material Disposition Program

PEIS Data Call Input Report: Ceramic Immobilization Facility with Radionuclides

February 9, 1996

University of California
Lawrence Livermore National Laboratory

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Work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

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Preface

Significant quantities of weapons-usable fissile materials (primarily plutonium and highly enriched uranium [HEU]) have become surplus to national defense needs both in the United States and Russia. The excess stocks of plutonium and HEU pose significant dangers to national and international security. The dangers exist not only in the potential proliferation of nuclear weapons but also in the potential for environmental, safety, and health consequences if excess fissile materials are not properly managed. Under the direction of the President of the United States, the Department of Energy (DOE) is examining options for placing weapons-usable nuclear materials in a form or condition that is substantially and inherently more difficult to use in weapons. The potential environmental impacts of facilities designed to implement this objective for plutonium will be described in the Fissile Material Disposition (MD) Program's Storage *and Disposition of Weapon-Usable Fissile Materials Programmatic Environmental Impact Statement* (PEIS).

The MD PEIS will examine the following resource areas: land use, facility operations and site infrastructure; air quality and acoustics; water, geology and soils, biotic, cultural and paleontological resources; socioeconomics; human health, normal operations and facility accidents; waste management; and transportation.

The purpose of this data call input report is to provide preliminary information for use in estimating the environmental effects associated with the construction and operation of a new Ceramic Immobilization Facility (CIF), an alternative currently under consideration in the MD PEIS.

The facility may be built at any location, but this MD PEIS data report is based on a new or generic (Greenfield) site located in Kenosha, Wisconsin. The construction of a "stand-alone" facility will require many support systems including radioactive waste treatment facilities, industrial waste treatment facilities, electrical utilities, domestic water facilities, and the infrastructure to support facility construction and operation (e.g., safeguards and security, transportation, fire protection, medical, purchasing, training, financial support). If this facility is constructed on an existing DOE site, many of these infrastructure elements will already be available. Additional studies will have to be performed so that environmental and geological reports can be generated that support the geographic site location in a facility Safety Analysis Report (SAR). The preliminary information presented in this data call includes only the environmental effects associated with the construction and operation of a new CIF. The economic advantages of building such a site on a DOE complex, from which existing support facilities and site data can be utilized will be given the proper consideration at a later time in the MD PEIS development process.

This alternative is one of several immobilization options being considered by the Fissile Material Disposition Program. Other options such as direct geologic disposition and mixed oxide fuel technology are also being considered.

Organizations that provided major contributions to the development of this report include:

- Lawrence Livermore National Laboratory
- Bechtel
- Australian Nuclear Science and Technology Organisation.

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1.0 Ceramic Immobilization Facility with Radionuclides—Missions, Assumptions, and Design Basis

1.1 Missions

The new Ceramic Immobilization Facility (CIF) accepts plutonium (Pu) in various forms and through a ceramic immobilization process converts it into an immobilized form that can be disposed of in a high-level waste (HLW) repository. The objective is to make the plutonium from the immobilized form as inherently unattractive and inaccessible as plutonium in spent fuel spent fuel from commercial reactors. The immobilized form is to be suitable for geologic disposal.

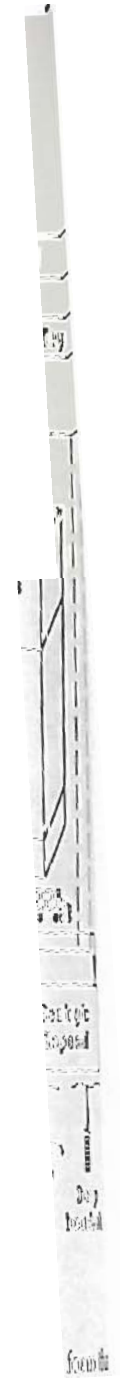
The ceramic immobilization alternative presented in this report consists of the immobilization of plutonium at a CIF in a titanate-based ceramic material and includes ^{137}Cs spiking to produce a radiation field in the final product.

1.1.1 Immobilization

Immobilization is the fixation of the surplus fissile materials in an acceptable matrix to create an environmentally benign form for disposal in a federal repository. In addition to the traditional characteristics required of an immobilization form to achieve isolation of the fissile material from the biosphere over geologic times, the immobilization form for the Fissile Materials Disposition (FMD) program must also possess the property that it is inherently as unattractive and inaccessible as the fissile material from spent fuel. The starting point for this latter requirement is part of the so called "spent fuel standard" invoked in the National Academy of Sciences (NAS) study on plutonium disposition. From this perspective HLW or other radioactive species, such as cesium (^{137}Cs), can be added with the fissile material into the waste form to create a radiation field which can serve as a proliferation deterrent. This immobilization process is shown conceptually in Fig. 1-1.

1.1.2 Ceramic Immobilization Form

The immobilization of HLW in a number of ceramic waste forms has been studied extensively since the late 1970s. The ceramic form that has received the most attention is a Synthetic Rock (Synroc) material. This is a titanate-based waste form composed primarily of zirconolite, perovokite, hollandite, and rutile phases. The ceramic waste form is attractive for immobilization of excess plutonium because of its extremely low leachability, existence of natural mineral analogues that have demonstrated actinide immobilization over geologic time scales, and the high solid solubility of actinides in the ceramic resulting in a reasonable overall waste volume.



uranium and thorium. Over 200 actinide bearing minerals are found in nature. A few of these are extremely promising for plutonium immobilization since they have demonstrated both immobilization of actinides and of decay products for periods exceeding 100 million years. The most geologic data are available for zircon ($ZrSiO_4$), monazite ($CePO_4$), and a few other related silica and phosphate minerals. However, substantial geologic data are also available for pyrochlore ($Gd_2Ti_2O_7$) and zirconolite ($CaZrTi_2O_7$) minerals, which are titania-based minerals. Because of demonstrated actinide immobilization, any of these minerals are strong candidates for plutonium disposition by immobilization in ceramic.

Because of their extreme durability, ceramics forms have been developed extensively for the immobilization of HLW. The material called Synthetic Rock (SYNROC) has received extensive study both at the Australian Nuclear Science and Technology Organisation (ANSTO) and at the Lawrence Livermore National Laboratory (LLNL). Work at ANSTO has included a full-scale demonstration facility using HLW surrogates and many small-scale experiments with plutonium. SYNROC is a titania-based ceramic composed approximately of 30% zirconolite, 30% hollandite ($BaAl_2Ti_5O_{16}$), 30% perovskite ($CaTiO_3$), and 10% rutile (TiO_2). Actinides partition into the zirconolite and perovskite phases. Radioactive cesium partitions into the hollandite phases. Cesium will be added to the form to provide a radiation field which will make the plutonium less attractive for reuse. The least durable phase is perovskite. For the plutonium disposition application, its presence is not required.

Considering the mineral analogues in nature and the status of development of ceramic HLW waste forms, a SYNROC formulation with a high zirconolite content is considered the baseline for the ceramic immobilization form. Composition after loading of plutonium and cesium is assumed to be 80 wt% zirconolite, 15 wt% hollandite, and 5% rutile. Future research and development may show other mineral formulations to be superior, and may become the preferred formulation.

Immobilization in the baseline formulation is accomplished by elemental substitution of the plutonium and cesium into lattice sites of the host minerals. Plutonium can substitute for the zirconium site if it is in the +4 valence, or it can substitute for the calcium site if it is in the +3 valence. The plutonium substitutes more readily into the calcium site, because the size of the +3 plutonium atom matches the +2 calcium atom more closely than the size of the +4 plutonium atom matches the +4 zirconium atom. Maximum plutonium loadings are about 10 wt% on the zirconium site and about 23 wt% on the calcium site. Higher loadings yield the pyrochlore phase which is also a desirable phase for actinide immobilization. If the SYNROC formulation is 80 wt% zirconolite and if processing conditions are sufficiently reducing, plutonium contents in the form exceeding 12 wt% are easily obtained.

Cesium is substituted into the barium site in the hollandite phase. It is considerably larger than the barium atom and is a different valence, but the lattice sites in hollandite are sufficiently large such that complete substitution for barium is possible. Maximum limit for cesium is around 23 wt%. If the SYNROC formulation contains 15 wt%

hollandite, then the maximum cesium loading in the overall formulation is 33[…] which vastly exceeds the requirement of 0.15 wt% to achieve the desired radia[…]

A small amount of titania is formulated into the form. This helps fix the pha[…] equilibria and allows for a small amount of variation in feed composition, both[…] loading of plutonium and in the amount of impurities present. Excess titania al[…] ensures that the product durability is optimized. Of all the oxide constituents i[…] formulation, titania is the most resistant to dissolution in water.

1.2 Assumptions and Design Basis

1.2.1 Program Assumptions

The following assumptions have been used to develop the flowsheets, block[…] diagrams, chemical input and output, etc. for the ceramic immobilization optio[…]

- The immobilization/pretreatment facility shall receive plutonium in the[…] the oxide (75%) or metal (25%).
- The nominal feed of plutonium over the life of the CIF is 50 tonne (50,0[…] 110,000 lb) of plutonium.
- The immobilized surplus fissile materials package shall contain an additio[…] of radiation to decrease its accessibility. The radiation field shall be grea[…] 0.26 C/kg/hr (1000 R/hr) at 1 m (3 ft) from the package center surface […] after initial fabrication; or some equivalent barrier shall be provided to r[…] the risk of diversion of the plutonium to weapons. For scoping purposes, […] gamma radiation field barrier shall be assumed. The source of the ^{137}Cs […] provided by capsules now stored at Hanford.
- The plutonium material loading in the ceramic immobilized form is a des[…] parameter involving multiple tradeoffs to be determined by the design. T[…] design loading will consider fission product availability as well as form […] facility size, safety factors, geologic waste form acceptance criteria, etc. The nominal loading for this study is 12% Pu (by weight).
- The immobilization package size shall not exceed a length of 3.0 m (10 ft[…] diameter of 61.0 cm (24 in.), and a mass of 2500 kg (5500 lb).
- Criticality considerations shall explicitly address both the immobilization processing/form fabrication with associated equipment (off-gas treatme[…] and repository storage for thousands of years into the future. Criticality c[…] by batch mass control or equipment geometry are the preferred methods […] considered during design. The use of neutron absorbers (e.g., gadolinium, samarium, hafnium, boron, etc.) shall be considered. Throughout this rep[…] neutron absorber is assumed to be gadolinium, but the use of other neutro[…] absorbers has not been ruled out. No criticality analysis has been perform[…] yet. Criticality design issues within this report are based on engineering judgments and extrapolation from similar processes only.

1.2.2 CIF Assumptions

The actual CIF may be built at a number of locations. The site assumed for this report is the standard Electric Power Research Institute (EPRI) site defined in Appendix F of *DOE Cost Guidelines*. After actual site selection, meteorological, geological, and environmental data specific to the site chosen will be required.

The general design basis document used in design of the Ceramic Immobilization Facilities is DOE Order 6430.1A, *General Design Criteria*. This order covers design criteria, applicable regulatory and industry codes and standards for the design of DOE nonreactor facilities. Design criteria for both conventional facilities designed to industrial standards and "special facilities" (defined as nonreactor nuclear facilities and explosive facilities) are included in this document.

Conventional design codes and standards have been used for the design basis of the non-nuclear facilities in the Ceramic Immobilization Facility including the following:

- Administration Building
- Support Utilities Building
- Warehouse
- Shops and Equipment Mockup Building
- Industrial Waste Treatment Building
- Sanitary Waste Treatment Building
- Cold Chemical Storage Building
- Facility Cooling Tower

Design codes and standards applicable to "special facilities" as defined in DOE Order 6430.1A include the following:

- Plutonium Processing Building
- Radwaste Management Building
- Hot Maintenance Facility
- Canister Storage Building
- Facility Guardhouses

A more detailed listing of compliance standards is presented in Section 1.2.5.

Previously encapsulated ^{137}Cs in a form compatible with the process will be used as the radioactive spike in the final ceramic product.

1.2.3 Facility Capacity/Capability

The CIF will have a 10-year production mission. The facility will process plutonium metal and oxide at a rate of 5 tonne (5000 kg; 11,000 lb) per year (50 tonne [50,000 kg; 110,000 lb] over the life of the facility). A 10-year mission is a conservative assumption, the actual production mission time will be optimized to maximum production at minimum duration.

Operations shall be three shifts per day, seven days per week. The CIF is assumed to operate with an availability factor of 75%. Allowing normal time for maintenance, accountability, criticality control, etc., normal operations shall be considered to be a 2[illegible] day operating year. Nominal throughput shall, therefore, be 8.34 kg (18 lb) of actinide per eight-hour shift.

Full storage capacity will be provided for Pu-ceramic canisters that will be produced during the operating mission.

Each Pu-ceramic canister would measure 36 cm (14 in.) in diameter by 2.4 m (96 in.) high with 12% by weight of plutonium in the ceramic, and weigh approximately 656 kg (1440 lb). Each canister is anticipated to contain 80 kg (176 lb) of plutonium, and approximately 64 canisters will be required to handle 5 tonne (5000 kg; 11,000 lb) of plutonium per year based on processing 50 tonne (56 ton) in 10 years; a total of approximately 640 canisters for the complete project.

Approximately 860 persons will be required to operate the CIF.

1.2.4 Facility Operating Basis

New immobilization facilities are assumed to be NRC licensed. The preliminary schedule, Fig. 1-2, shows the program start date as August 1996. The preliminary schedule indicated Title I (preliminary) design and preparation of license application with environmental report would require about four years. NRC licensing is estimated to require five years. However, nonsafety related construction is assumed to start about 2004, a year prior to issue of license. During the NRC licensing period, an Environmental Impact Statement is issued and Title II (final) design is completed. Construction, startup, preoperational testing, and operational readiness review are estimated to require about five years, leading to operation of the facilities about 2009. Operations are assumed to start about 2009 and be completed in 2018, for a nominal 10-year operating period. Decontamination and decommissioning of the facilities are estimated to require about three years, resulting in overall program completion date of 2020.

A new capital project will be required to implement the greenfield plutonium immobilization alternatives, which include the design and construction of new facilities. An assumption is that DOE line item projects will be conducted in accordance with DOE orders and the congressional funding cycle. The planning basis is that key decisions (KD) for Approval of Mission Need (0), Approval of New Start (1), Commence Detailed Design (2), Commence Construction (3), and Commence Operations (4) will be performed by the DOE in support of this plutonium immobilization alternative.

A research and development program has been identified to develop and demonstrate the process and equipment and the ceramic product.

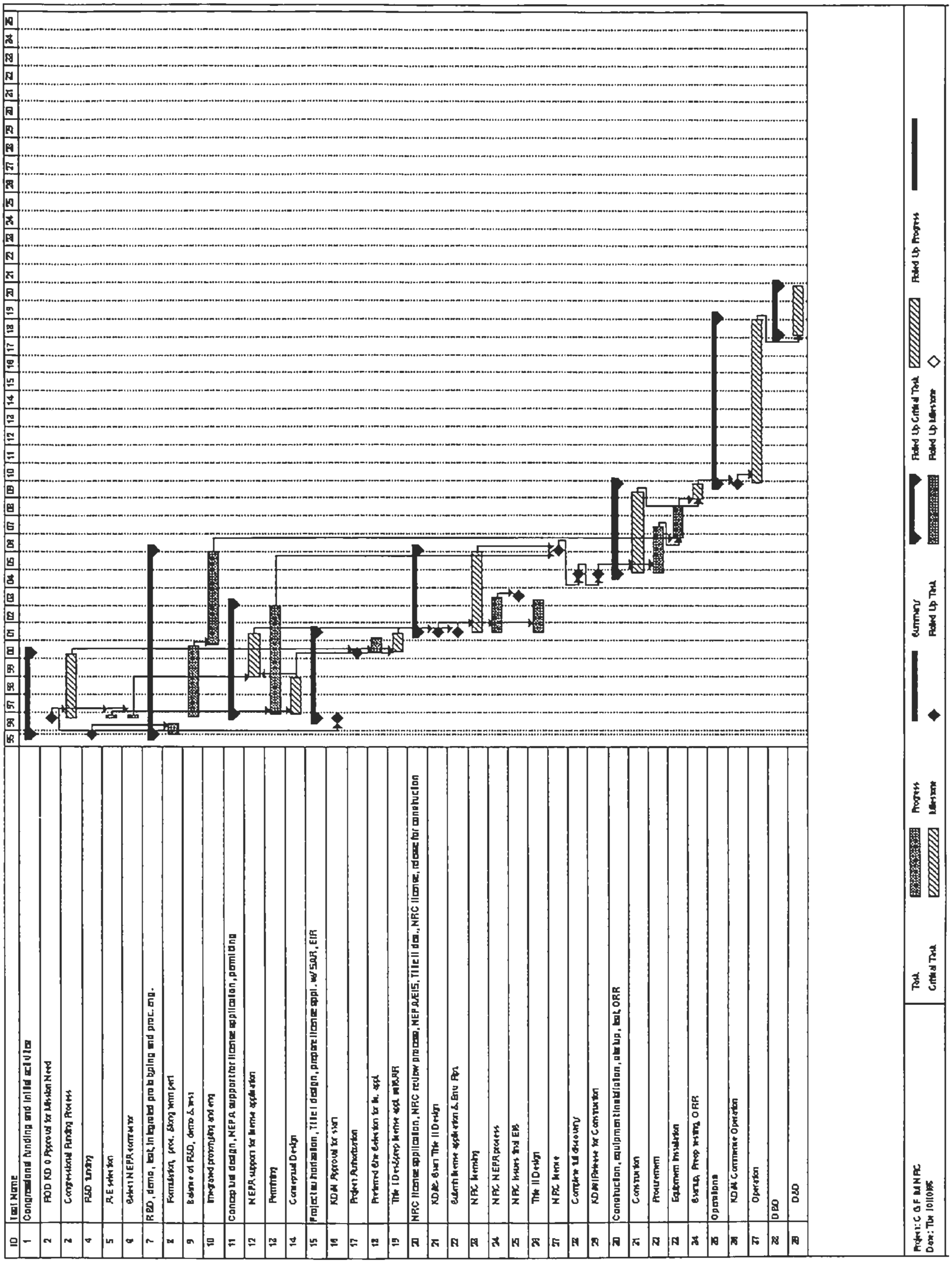


Figure 1-2. Schedule.

National Environmental Protection Act (NEPA) activities are included. For NRC licensed facilities it is assumed that an environmental information report, preferred site, and evaluation of alternatives is submitted to NRC for their NEPA to issue a license.

Permitting activities are indicated. Preparation of a Safety Analysis Report is included. Title I & II (preliminary and detailed) design durations are indicated. Construction and procurement durations are included. Cold startup, preoperation testing, and an Operational Readiness Review (ORR) of the facility is included, by hot startup and operations.

The time to process the reference 50 tonne (56 ton) of plutonium will vary with plutonium loading and actual operating scenarios. For planning purposes, the estimated duration of the plutonium immobilization campaign is 10 years. Process improvements, plutonium immobilization experience, and increased plutonium could shorten this schedule.

Decontamination and decommissioning duration is included. The decommis method assumed for the schedule is complete dismantlement and restoration of for unrestricted use. Other methods (layaway, protective storage, etc.) or combi of methods, depending on time, cost benefit studies, or radiation exposure, might selected with an impact to the time required.

1.2.4.1 Research and Development Basis. The duration and scope of the res and development program must be sufficient to develop and demonstrate the immobilization processes and to assess the durability and performance of the immobilized ceramic product. It is assumed that the bulk of the research and development would occur between the ROD and the end of Title I design. Prim research and development tasks will be required to:

- Determine and document the nuclear criticality safety margins of every st plutonium in handling, processing, and final disposition in a repository;
- Define the chemical and physical properties of the ceramic product, inclu precursor composition and product durability; and
- Develop and demonstrate acceptable performance of equipment, processes final immobilized form.

A considerable amount of research and development has already been perform for immobilizing HLW in ceramic. Ceramic processes have been demonstrated f scale using HLW simulant solutions. Small scale work on product durability and performance has also been performed for plutonium and cesium loaded ceramics

The primary safety consideration in the processing and final disposition of the plutonium is criticality safety. All handling and processing must be in complian DOE Order 5480.24, *Nuclear Criticality Safety*. This order dictates that before a new operation is begun, it shall be determined that the process will be subcritical unde normal and credible abnormal conditions. The ceramic immobilized form will co various neutron absorbers (e.g., hafnium, gadolinium, samarium, etc.) to prevent criticality. Even with the neutron absorbers present, assessments and procedures must be identified and documented according to accepted practices to ensure that criticality cannot occur.

The chemical and physical properties of the immobilized product are also extremely important. Properties of significant interest are leachability in ground waters, susceptibility to radiation damage effects, chemical stability in a repository, and thermal shock resistance during fabrication. Ceramic will be formulated to optimize these properties without limiting the solid solubilities of the plutonium, neutron absorbers, or cesium. In addition, the effects of feed material form, composition, and morphology and process kinetics and reaction times will need to be evaluated in order to optimize the product properties.

Demonstration of reliable procedures, equipment, and product properties will be important to build confidence in the ceramic fabrication process and product. This will encompass large scale demonstrations of the immobilization process and performance assessments of the product. The fabrication process data will be used to identify processing rates, operating limits, and related operational performance characteristics to guide design and construction. The product performance data will be used to determine long term performance of the repository and to certify the immobilized form.

1.2.4.2 Permitting/Licensing Basis. The ceramic immobilization in the GVF will require compliance with applicable laws, regulations, executive orders, NRC regulations, and DOE orders. Implementing procedures will govern permit/license acquisition. This section identifies the major regulatory requirements that must be addressed.

The general DOE order applicable to the facility design is DOE Order 6430.1A, *General Design Criteria*. Applicable codes, standards, guidelines, etc., as referenced in Section 0106, "Regulatory Requirements," of DOE 6430.1A shall apply. More specific criteria can be found in Division 13, "Special Facilities"; Sections 1300, "General Requirements"; 1304, "Plutonium Processing and Handling Facilities"; 1305, "Plutonium Storage Facilities"; 1323, "Radioactive Liquid Waste Facilities"; 1324, "Radioactive Solid Waste Facilities"; and 1325, "Laboratory Facilities."

1.2.4.3 Construction Basis. A new capital project will be required to implement this ceramic immobilization alternative, which includes the design and construction of a new facility. The DOE line item projects must be conducted in accordance with DOE orders and the congressional funding cycle. In certain clearly specified circumstances, the applicable DOE Orders (4700.1 and 6430.1) allow parallel rather than prescribed sequential activities. Nevertheless, certain milestones are inviolable. A conceptual design and preliminary cost estimate will be developed for DOE validation. The DOE will likely validate the project approximately two years ahead of the project Budget Year.

Key decisions for Approval of Mission Need (KD-0), Approval of New Start(Commence Detailed Design (KD-2), Commence Construction (KD-3), and Comme Operations (KD-4) will be performed by the DOE in support of this ceramic immobilization alternative.

1.2.4.4 Operating Basis. The time to process the reference 50 tonne (56 ton) of plutonium into ceramic will vary with the plutonium loading, but in general, proc times to support the immobilization mission can be achieved. The estimated dura of the ceramic immobilization campaign will be 10 years. Operations shall be thre shifts per day, seven days per week. Allowing normal time for remote maintenan accountability, criticality control, etc., a normal operating year should be 200 days.

Nominal throughput will, therefore, be 8.34 kg (18 lb) of plutonium per eight-h shift. The operating schedule assumes 10 years of operation with the last year preparing for decontamination and decommissioning (D&D) activities. Process improvements, plutonium ceramic experience, and increased plutonium loading c shorten this schedule, so 10 years is a conservative maximum operating span.

1.2.4.5 Decontamination and Decommissioning Basis. The decommissioning method assumed for the CIF will be complete dismantlement and restoration of th for unrestricted use. Other methods (layaway, protective storage, etc.) or combina of methods, depending on time, cost benefit studies, or radiation exposure, may be selected.

An aggressive schedule for D&D activities is indicated which includes facility transition, project preparation, environmental review, engineering and planning, D operations, closeout and verification, and postoperations.

1.2.5 Compliance

1.2.5.1 Rules, Regulations, Codes, and Guidelines. Basic references concerning content and procedures for issuing an EIS can be found in the Council on Environme Quality Regulation 40 CFR 1502, *Environmental Impact Statement*; 10 CFR 1021, *Nation Environmental Policy Act Implementing Procedures* (for DOE); DOE Orders 5400.1, *Ge Environmental Protection Program*, and 5440.1E, *National Environmental Policy Act Compliance Program*.

The general DOE order applicable to the facility design is DOE Order 6430.1A, *General Design Criteria*. Applicable codes, standards, guidelines, etc., as referenced i Section 0106, "Regulatory Requirements," of DOE 6430.1A shall apply. More speci criteria can be found in Division 13, "Special Facilities"; Sections 1300, "General Requirements"; 1304, "Plutonium Processing and Handling Facilities"; 1305, "Plutonium Storage Facilities"; 1323, "Radioactive Liquid Waste Facilities"; 1324, "Radioactive Solid Waste Facilities"; and 1325, "Laboratory Facilities."

Applicable USNRC regulatory guides referenced in DOE Order 6430.1A will be us where appropriate.

1.2.5.2 Safeguards and Security. The basic compliance document for safeguards and security requirements for the facility design is DOE Order 6430.1A, *General Design Criteria*, Section 1300-10, and the 5630 series of DOE orders. Specific references applicable to the safeguards and security systems provided in the design are discussed in detail in Sec. 2.3 of this report.

1.2.5.3 Environmental, Safety, and Health (ES&H). ES&H requirements will generally follow DOE Order 5480.4, *Environmental, Safety and Health Protection Standards;* DOE Order 5480.1B, *Environmental Safety and Health Program for DOE Operations*; and DOE Order 5440.1C, *National Environmental Policy Act*. Requirements for the facility fire protection systems will be in accordance with DOE Order 5480.7, *Fire Protection.* Criticality safety will follow DOE Order 5480.24, which endorses ANSI/ANS Standards 8.1, 8.3, 8.5, 8.7, 8.15, and 8.19, with exceptions. Details of these requirements are covered in Section 2.2 of this report.

1.2.5.4 Buffer Zones. The need for buffer zones surrounding the facility will be determined during the site-specific environmental impact studies that will follow these programmatic EIS studies. In general, siting criteria will follow DOE Order 6430.1A, Sections 0200-1, "Facility Siting"; 0200-2, "Building Location"; and 0200-99, "Special Facilities." Effluent releases will not exceed limits referenced in DOE 5400.1, *General Environmental Protection Program Requirements*; the directive on "Radiation Protection of the Public and the Environment" in the DOE 5400 series; and DOE Order 6430.1A, Section 1300-9, "Effluent Control and Monitoring."

1.2.5.5 Decontamination and Decommissioning /Conversion. Design requirements for decontamination and decommissioning for the facility will be in accordance with DOE Order 6430.1A, Section 1300-11, "Decontamination and Decommissioning (of Special Facilities)"; Section 1304-8, "D&D of Plutonium Processing and Handling Facilities"; and 1325-6, "D&D of Laboratory Facilities."

1.2.5.6 Nonsafety/Safety Class Systems, Components, and Structures. Nonsafety class systems, components and structures will be designed to normal industrial standards. Nonsafety class structures will be designed to the International Conference of Building Materials Uniform Building Code (UBC). Nonsafety class electrical systems and components will be designed to appropriate Institute of Electrical and Electronics Engineers (IEEE) standards. Other nonsafety class systems and components will be designed to appropriate industrial standards as listed in DOE Order 6430.1A, Section 0109, "Reference Standards and Guides."

Safety class systems, components, and structures will be designed to the requirements of DOE Order 6430.1A, Section 1300-3, "Safety Class Criteria"; and 1300-4, "Nuclear Criticality Safety."

The facility safety analysis and risk assessment will comply with DOE Orders 5480.23, *Nuclear Safety Analysis Reports* and 5481.1B, *Safety Analysis and Review System;* and DOE Order 6430.1A, Section 0110-5.2, "Safety Analysis."

Design basis natural phenomena (i.e., design-basis earthquake, design-basis tor and design-basis flood) will be chosen in accordance with DOE-STD-1020-92, *Desi Evaluation Guidelines for DOE Facilities Subject to Natural Phenomena Hazards.* Accide risk assessments will be in accordance with DOE-STD-3005-YR, *Evaluation Guideli Accident Analysis for Safety Structures, Systems, and Components.*

1.2.5.7 Toxicological/Radiological Exposure. Exposures to hazardous effluen (both radioactive and nonradioactive) will not exceed the limits referenced in DOE Order 5400.1 and the directive on Radiation Protection of the Public and the Environment in the DOE 5400 series. Effluent control and monitoring will be in accordance with DOE Order 6430.1A, Section 1300-9, "Effluent Control and Monit (of Special Facilities)."

1.2.5.8 Waste Management. Waste management systems provided for the facil will be in accordance with the requirements of DOE Order 6430.1A, Section 1300- "Waste Management (for Special Facilities)"; Section 1304-7, "Effluent Control and Monitoring (of Plutonium Processing and Handling Facilities)"; 1305-6 "Effluent Control and Monitoring (of Plutonium Storage Facilities)"; and 1324-7, "Effluent Control and Monitoring (of Radioactive Solid Waste Facilities)."

Specific DOE design and operating requirements for radioactive wastes (inclu low-level waste and TRU waste) appear in DOE Order 5820.2A, Radioactive Wast Management. Nonradioactive, hazardous waste requirements appear in DOE 54 and applicable sections of 40 CFR 264, 265, 267, and 268. A DOE pollution-preven program—including waste minimization, source reduction and recycling of solid and air emissions—will be implemented in accordance with DOE Orders 5400.1, General Environmental Protection Program, and 5820.2A, Environmental Complia Issue Coordination.

2.0 Ceramic Immobilization Facility Description

2.1 General Facility Description

2.1.1 Functional Description

The process presented in this report consists of immobilization of plutonium in a ceramic form spiked with radioactive cesium to discourage diversion. The feed materials are plutonium in both the oxide and metal form, cesium chloride, and nonradioactive ceramic precursor materials. Gadolinium (or samarium, hafnium, etc.) is added as a neutron absorber for criticality control during ceramic processing and final product storage. The plutonium and gadolinium are mixed as soluble compounds to ensure intimate mixing and to prevent settling should agitation be lost.

The final ceramic product is contained in canisters and is stored onsite until it is transported to its final disposition. Each product canister contains 20 compressed bellows with about 660 kg (1,450 lb) of ceramic, which includes approximately 80 kg (176 lb) of plutonium, 52 kg (114 lb) of gadolinium and 1 kg (2.2 lb) (3.2×10^6 GBq; 87,000 Ci) of cesium.

The processing is performed in gloveboxes and shielded concrete cells. Plutonium processing prior to adding cesium is conducted in shielded gloveboxes. Cesium processing and plutonium processing after adding cesium are conducted in remotely operated, shielded cells.

The ceramic product is assumed to be similar to Synroc-C, which contains the following mineral phases: zirconolite ($CaZrTi_2O_7$), hollandite ($BaAl_2Ti_6O_{16}$), perovskite ($CaTiO_3$), and rutile (TiO_2). The actual phases selected will be the result of a research and development program, and it is assumed that the composition of the ceramic-forming chemicals (precursors) will not affect the processing equipment or sequence.

Figure 2-1 is a flow diagram that depicts the process through the Ceramic Immobilization Facility.

2.1.2 Plot Plan

The Ceramic Immobilization Facility plot plan is shown in Fig. 2-2. The major structures on the site include the following:

- Plutonium Processing Building
- Radwaste Management and Hot Maintenance Buildings
- Canister Storage Building
- Miscellaneous support buildings, including

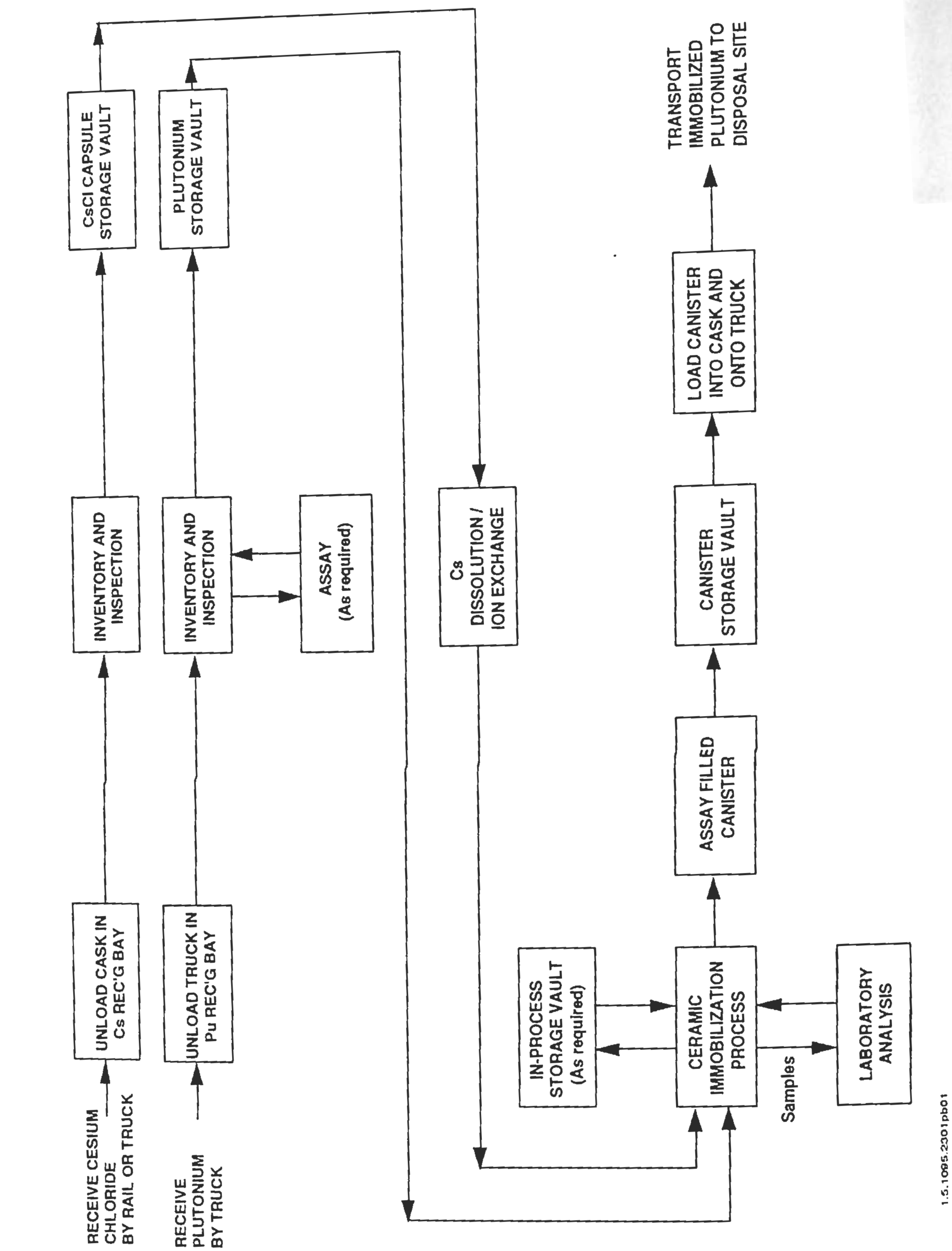
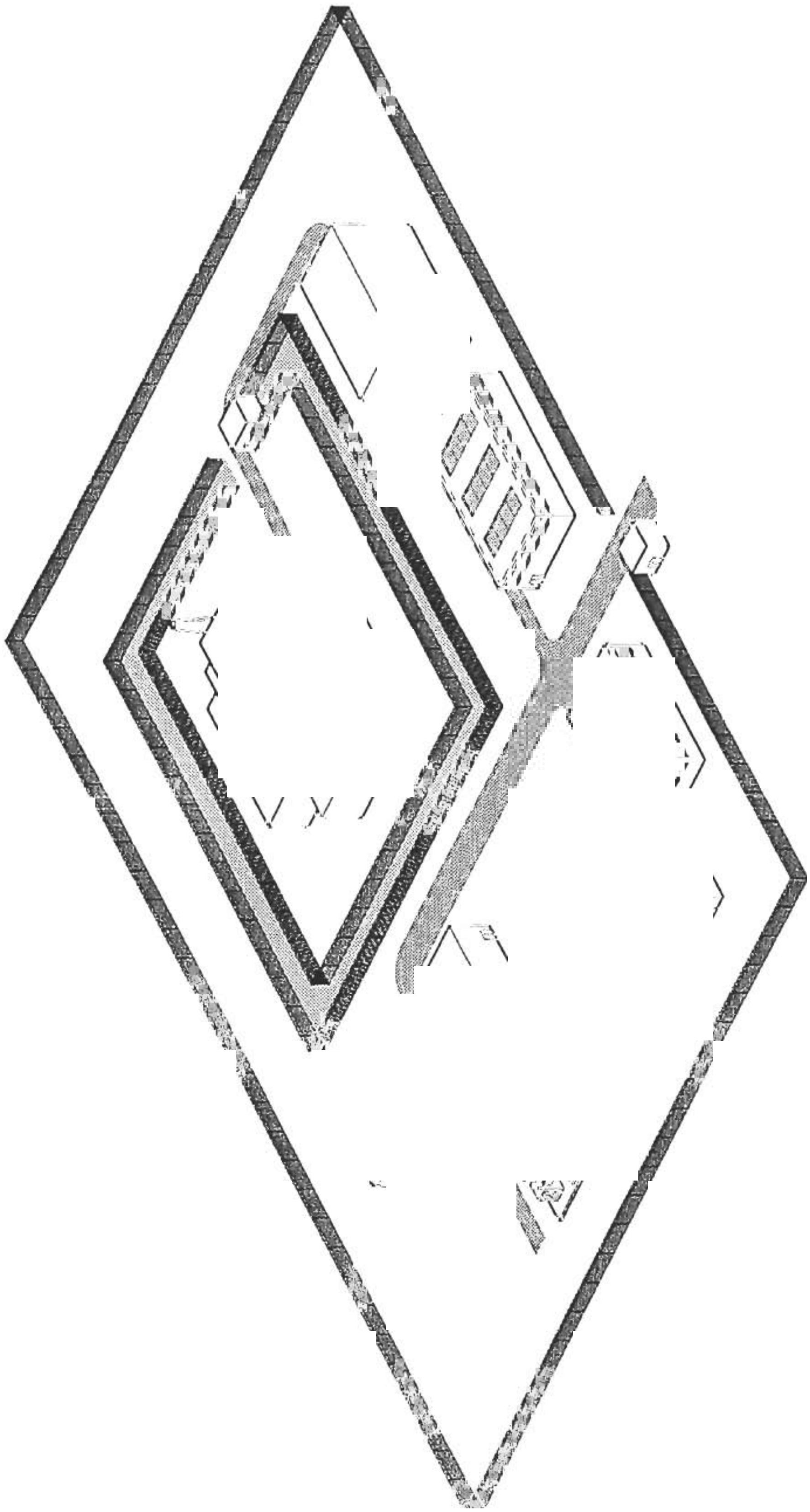


Figure 2-1. Material flow diagram.



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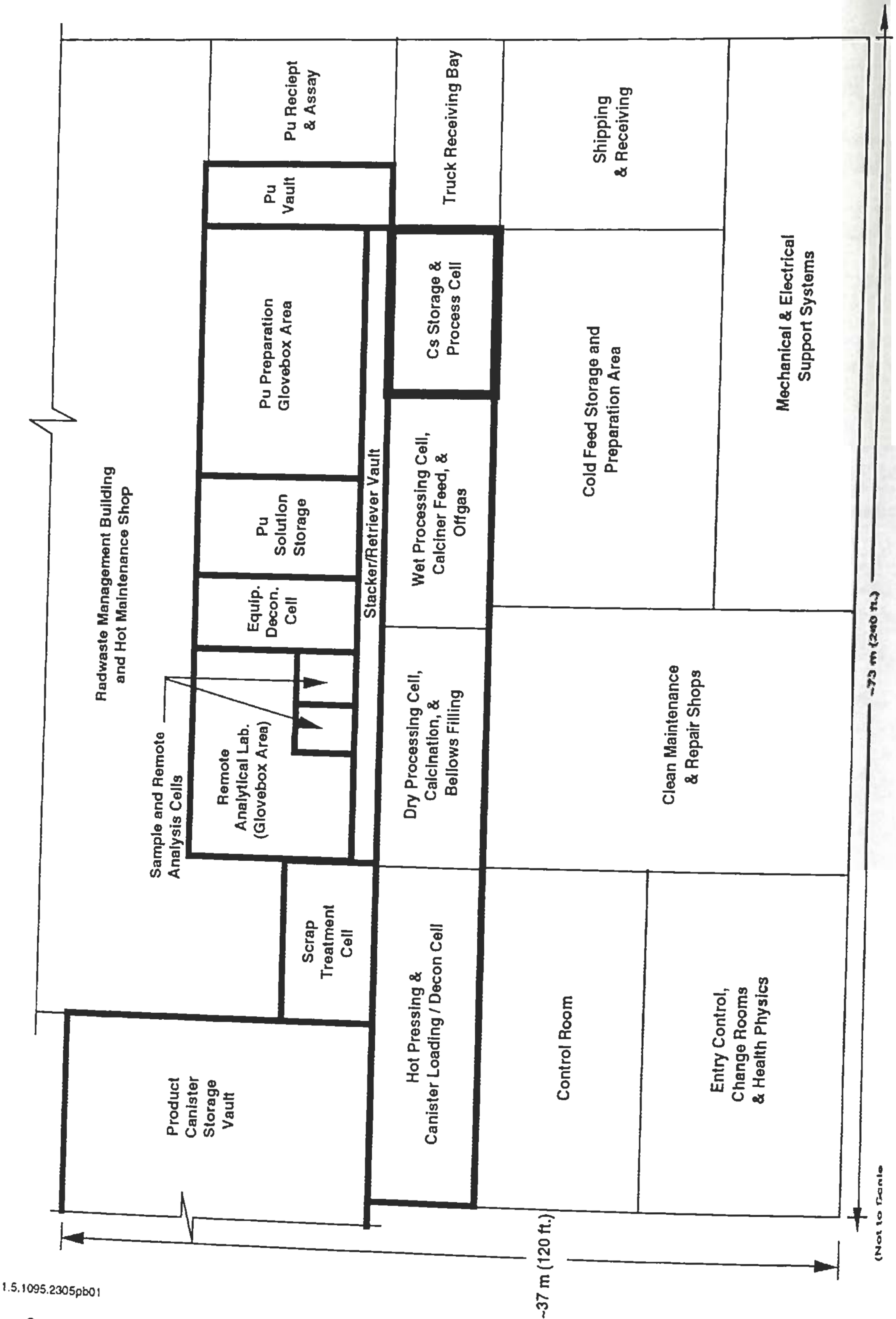


Figure 2-3. Plutonium processing building layout.

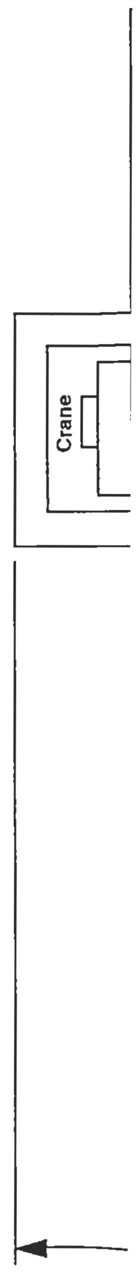


Figure 2-4. Pu process

- Scrap treatment cell to allow treatment and recycling of plutonium from contaminated process materials.
- Area for entry control to the facility, personnel rooms, and health physics operations.

The Plutonium Processing Building (see Fig. 2-2) is immediately adjacent to the Radwaste Management Building for handling, treatment, packaging, and shipp low-level and TRU wastes; and the product Canister Storage Building, which is store one year of canister production with space provided for an additional nine capacity.

The facility will be designed in accordance with DOE Order 630.1A, General *Criteria*.

The plutonium processing equipment upstream of cesium addition—includi plutonium metal size reduction, plutonium metal oxidation, and plutonium oxide dissolution—is housed in glovebox enclosures located in processing rooms exter the remote processing cells. Glovebox equipment layout is grouped by primary p operations. Normal process operations will be controlled remotely from a process control room with minimum manual intervention. Both liquid and solid material transfers within and between gloveboxes will be accomplished by remotely oper pumps, vacuum transfers, conveyors, robots, manipulators, etc., as required. Maintenance of equipment within the process gloveboxes will be done with glove remote removal of plutonium from the process equipment.

Process equipment containing cesium is generally located within shielded pro cells. This equipment is remotely operated and maintained. The maintenance philosophy and cell layout are similar to those used for the Defense Waste Process Facility (DWPF) at the Savannah River Site. All equipment within the cell will be designed for remote removal. Remote connectors operated by an overhead crane used to remotely install and remove equipment, piping, electrical connectors, etc. Closed-circuit television (CCTV) viewing and remotely operated in-cell robots, manipulators, cranes, etc. as required are employed in liquid processing areas. CC and remotely operated maintenance cranes, manipulators, etc. will be supplement shielding windows and manually operated manipulators as required in areas whe solid materials are handled within the cells.

Cell shielding wall thickness is assumed to be approximately 1.4 m (4.5 ft) for the cesium capsule storage and handling areas and about 1.2 m (4 ft) for the remainder the processing and canister handling cells.

Typical cell layouts are shown on Figs. 2-5 through 2-9.

The process support systems are housed primarily within the process building, except for the process gas supply systems, which will be located in the yard adjac the process building.

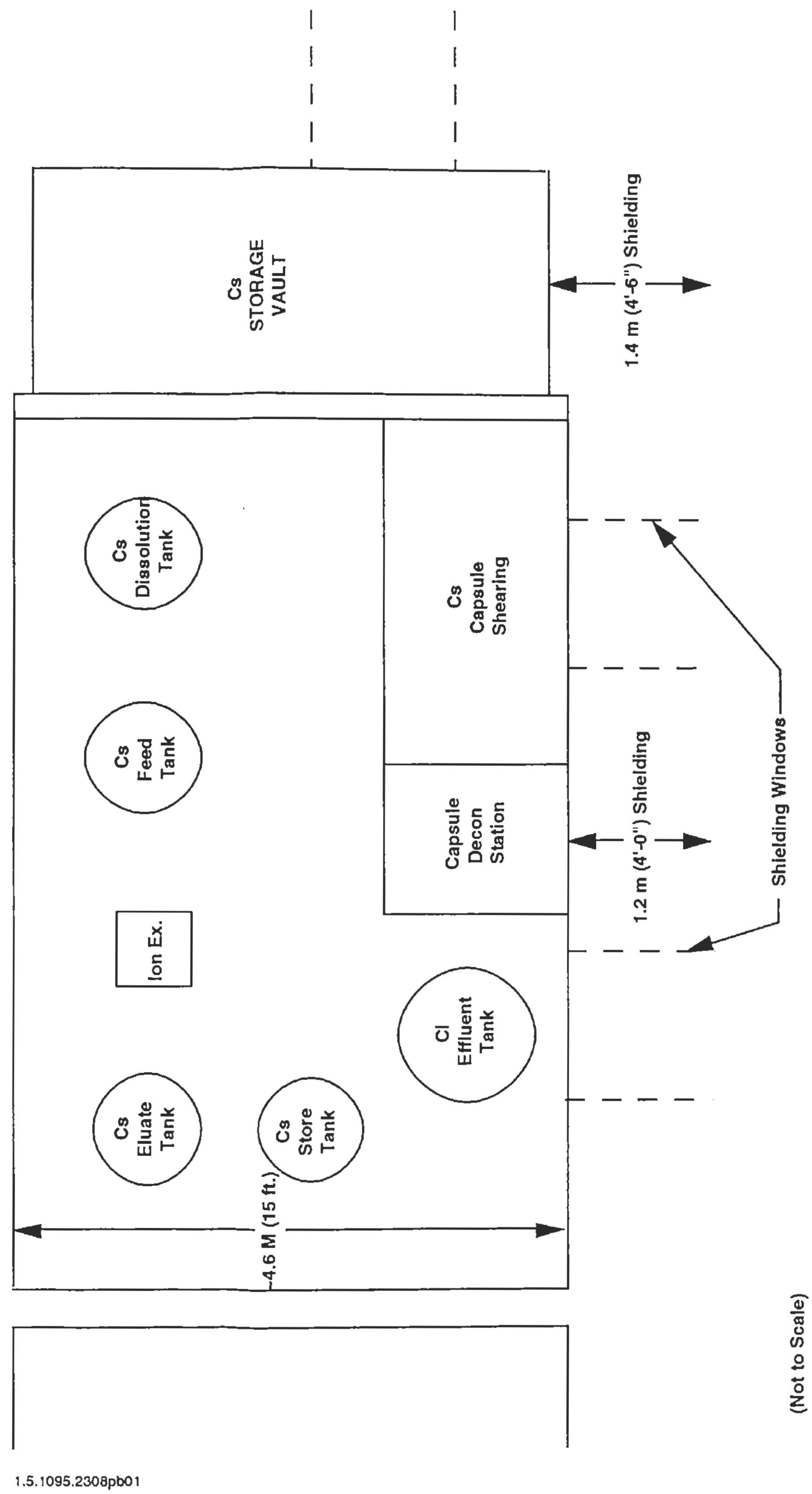
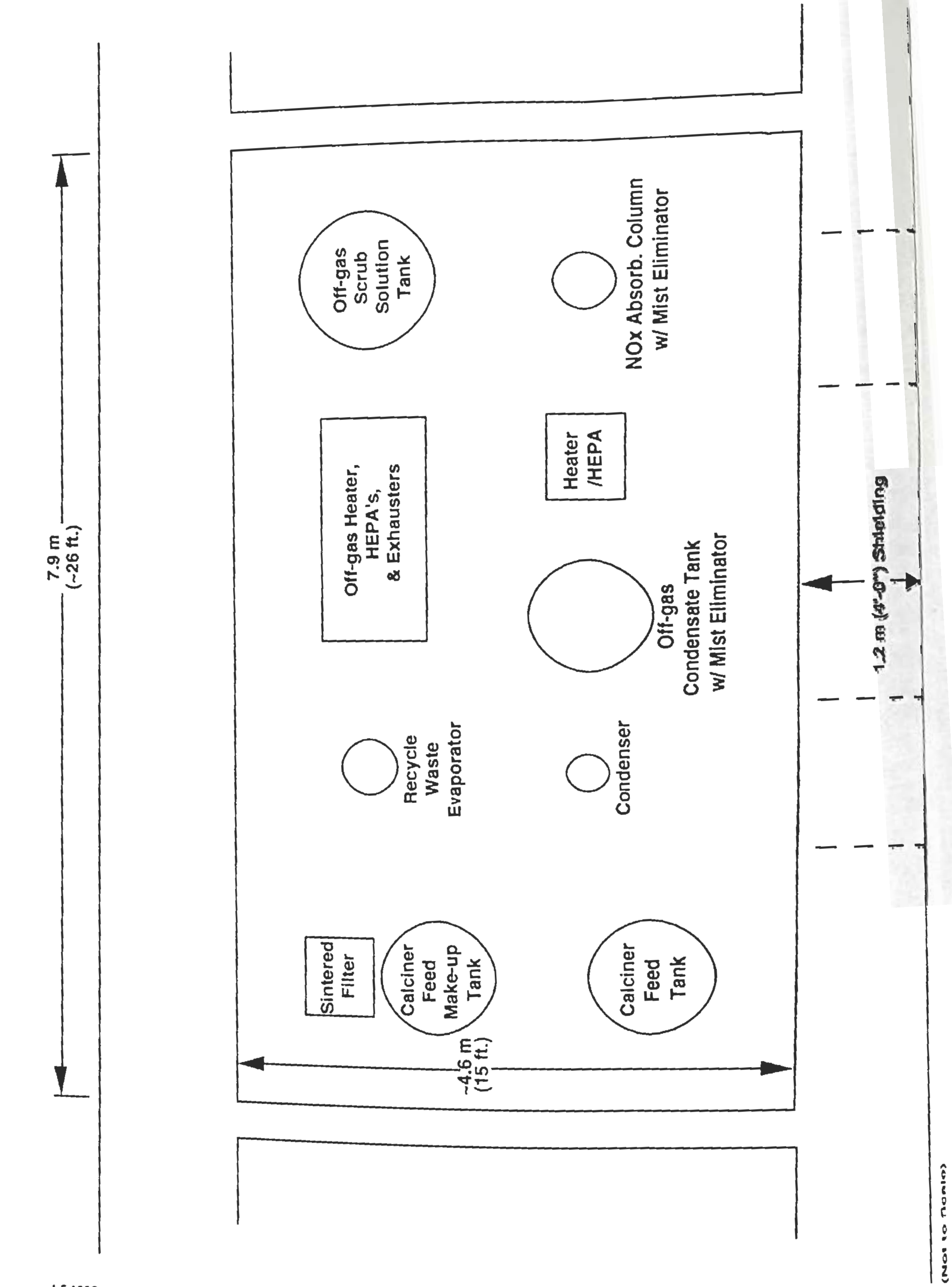


Figure 2-5. Cesium processing cell equipment layout.



1.5.1095.2309pb01

Figure 2-6. Wet processing, calciner feed and off-gas cell equipment layout.

Figure 2-7.

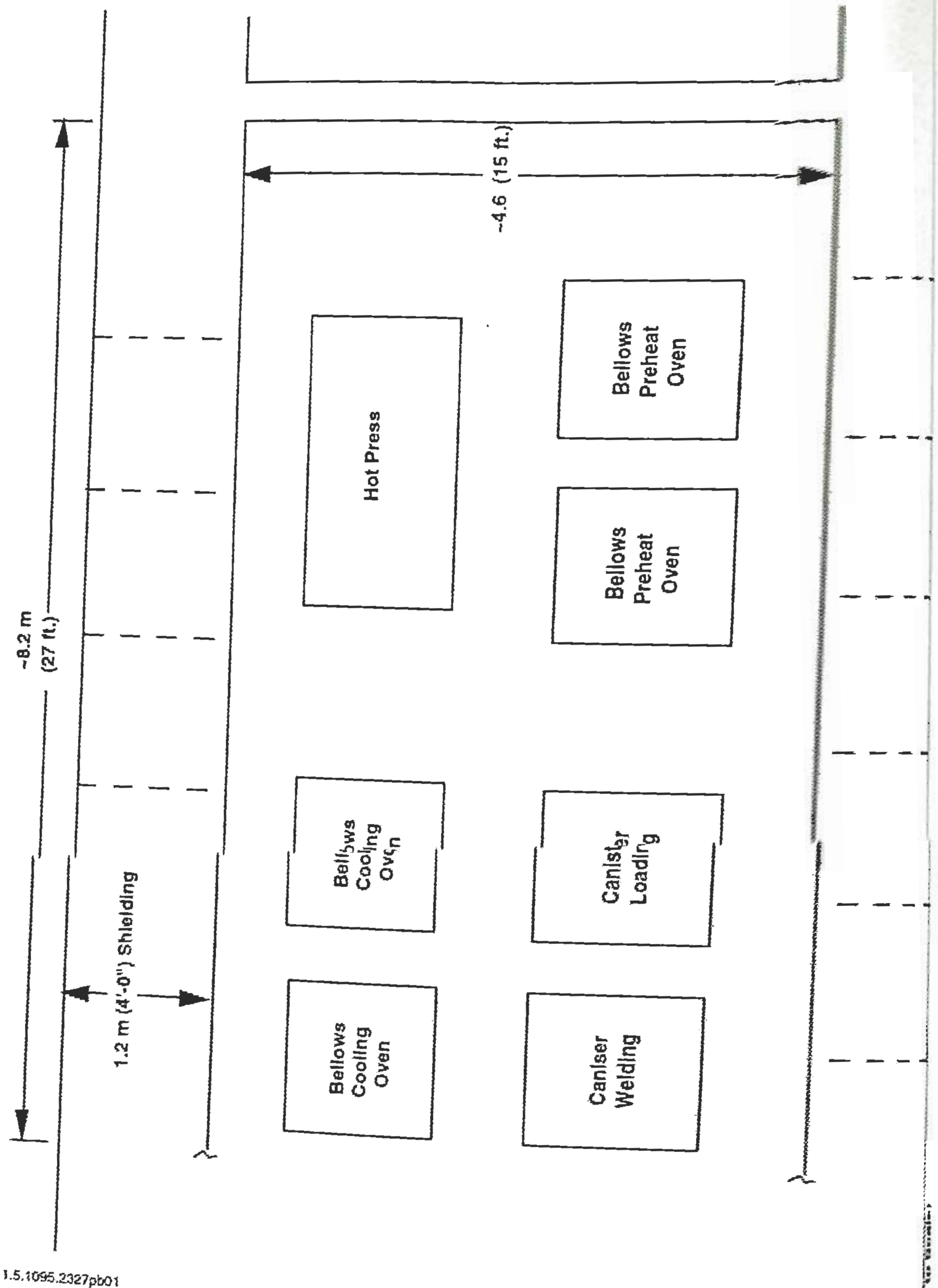


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Figure 2-8. Hot pressing and canister loading/decontamination cell (loading sectic equipment layout.

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The plutonium feed material storage and handling system consists of a pluton shipping container crane; a plutonium storage container unloading, weighing, bar reading, and assay device; and a plutonium storage container transfer device. The ^{137}CsCl receiving, handling, and storage system consists of a cask handling crane unload and return incoming ^{137}CsCl casks and a remotely operated cesium capsu transfer cart to transfer cesium capsules to storage. A cask unloading cell is provi unloading and storing incoming ^{137}CsCl casks.

A plutonium storage vault meeting the requirements of DOE Order 6430.1A, Section 1305, with a capacity of three months feed and served by a stacker-retriever provided. Six months storage of incoming ^{137}CsCl capsules is also provided in a shielded cesium capsule storage cell.

The process material handling system will consist of remotely operated conve within and between glovebox enclosures for the plutonium processing "head end" the facility to provide for confined material transfers.

A remotely operated stacker-retriever will provide material transfers to and fro storage of plutonium-containing materials, samples, etc. within a storage vault adja to the process glovebox areas and the process cells. In-cell material handling equip will consist of remotely operated cranes, manipulators, robots, etc., as required to transfer process materials between process operating areas. CCTV and supplemen shielding windows and manually operated manipulators will be provided, as requ for selected operating stations.

Product canister storage and handling is provided by a system similar to the th used for the DWPF. A shielded canister transporter equipped with a bottom-loading cask designed for safe transport of filled canisters to and from the canister storage is provided. Storage of canisters is in below-grade shielded storage positions provi with shield plugs, air convection cooling, and a computerized tamper-indicating sys to monitor and permit only authorized canister movement. Initial onsite storage capacity is one year, with space provided for expanding this capacity to the full 10 y of operation.

In-cell maintenance systems consist of dedicated cell cranes, manipulators, imp wrenches, CCTV, shielding windows, etc., to allow remote removal of all in-cell components to a shielded decontamination cell equipped with remotely operated decontamination systems. Equipment, piping, and other components can be decontaminated in the equipment decontamination cell to levels that will allow con maintenance or disposal as low-level or TRU waste. If radiation levels remain high, equipment can be remotely removed, placed in a suitably shielded shipping contain and sent to an onsite hot maintenance building or shipped to offsite disposal. A gen purpose overhead crane serving all cells is provided above the cells to remove the c covers and remove and transfer cell equipment and components to the equipment decontamination cell or to a loadout air lock.

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in Hot Maintenance Shop operations will be transferred to the adjacent [illegible] Management Building to be packaged for shipment offsite.

- An approximately 30-m × 60-m (100-ft × 200-ft) metal-framed, standard-construction Shops and Mock-up Building, which houses clean maintenance, fabrication, and repair shops for equipment, piping, and electrical cond[illegible] remotely operated areas of the plutonium processing building.
- The Support Utilities Area, located outside the inner security fence, includ[illegible] water treatment systems, water storage tanks for 95,000 L (25,000) gal of [illegible] water and 190,000 L (50,000 gal) of service water, 900,000 L (240,000 gal) [illegible] water storage, redundant 8000 Lpm (2,000-gpm) fire-water pumps and a [illegible] 30-m (100-ft × 100-ft) metal framed building to house all equipment. The [illegible] also houses the central chilled-water cooling and steam-heating boiler sys[illegible]
- The cooling tower, a multiple-cell, wood-construction, induced-draft, cro[illegible] type tower with a capacity of 9,500 Lpm (2,500 gpm) to provide cooling for the process and HVAC systems.
- An approximately 1,400-m^2 (15,000-ft^2) Administration Building.
- An approximately 1,900-m^2 (20,000-ft^2) Warehouse.
- The Industrial Waste Treatment Facility for the receipt, treatment and disp[illegible] noncontaminated chemical, liquid and solid wastes other than liquid was[illegible] disposed of through the sanitary waste system.
- Utility wastewater discharges, including cooling tower and boiler blowd[illegible] cold chemical area liquid effluents and nonradioactive liquid ceramic ad[illegible] liquid wastes, will be treated and discharged in this facility to ensure that wastewater discharges meet applicable environmental standards.
- An on-site sanitary treatment plant will treat sanitary wastes generated fr[illegible] operations.
- The Sanitary Waste Treatment Facility, with a capacity of 38,000 Lpd (10,0[illegible] gpd).
- The perimeter security system, including a guardhouse at each entry poin[illegible] site and to the inner security area. All facilities in which radioactive materi[illegible] handled, and facilities necessary for safe operation of the process facilities [illegible] surrounded by double security fences within the outer site perimeter fence.

Compressed-air systems include plant air, instrument air, and breathing air. A [illegible] set of two, redundant, 14000-Lpm (500-cfm), reciprocating air compressors provid[illegible] compressed air to the plant and instrument air systems. The plant air system is provided through a receiver set at 700 kPa g (100 psig). Instrument air is dried in desiccant type air dryers to a dewpoint of –40°C (–40°F) and is supplied to a pipi[illegible] distribution system from a separate air receiver set at 700 kPa g (100 psig). The breathing air system provides air to breathing-air manifolds located throughout the Plutonium Processing Building.

Cooling of process equipment is provided by a closed-loop cooling-water syste[illegible] which is cooled with water from the cooling tower in plate-type heat exchangers. T[illegible] closed cooling loop isolates any radioactive contamination should a leak occur in [illegible] of process equipment. The loop is monitored continuously for contamination, and ovision is made to use a deionization column to clean the closed loop should any ntamination occur.

Building HVAC systems use a central chilled-water system for building cooling. ıree 50%-capacity, 1.2-MW (350-ton), centrifugal water chillers and three 1500-Lpm 00-gpm) circulating pumps are provided.

All cooling water systems are connected to the cooling-tower system.

A central steam plant is provided in the Support Utilities Building to produce steam r process uses and for building heating by the HVAC systems. The plant produces 000 kg/hr (30,000 lb/hr) of 350 kPa g (50-psig) steam, which is distributed around the te by outside overhead piping.

The site receives electric power at 13.8 kV from the utility grid system and stributes it onsite at the required voltages. The Electrical Substation has a capacity of 00 kW and includes the primary switching and voltage transformer facilities for the te. The electrical system also includes two, redundant, 500-kW, emergency-power esel generators, housed in a seismic- and tornado-resistant structure, to ensure the eration of all safety-related systems during a power outage. Uninterruptible power ıpply (UPS) systems are provided for the control system to ensure continued eration of safety-related equipment and systems during a power outage.

2 Design Safety

Special design considerations are required to ensure that (1) radioactive solutions are roperly contained during processing operations, (2) ventilation air from process erations is properly filtered, (3) operating personnel are adequately protected from idiation and airborne contamination, and (4) process streams are properly treated and andled for release or disposal. The total confinement system consists of one or more idividual confinement barriers and systems that restrict releases of radioactive or azardous materials to the environment or into areas normally occupied by plant ersonnel. Engineered safety features are designed and used to prevent radioactive aterial and hazardous chemical releases. Development of the CIF for plutonium nmobilization will require incorporation of these requirements through the following ystems:

- **Confinement systems and barriers** - Two types of confinement barriers are used in the facility. "Total barriers" are those fabricated of material that prevent penetration of confined material without regard to the physical or chemical nature of the material. "Selective barriers" are mass transfer devices or filters to remove selected chemicals or particulate matter from a process or ventilation stream while allowing the bulk of the stream to pass. Barriers are designed to withstand loadings due to pressure differentials imposed by the process off-gas, building ventilation systems and pressure differentials caused by natural phenomena. Confinement systems are constructed of nonflammable materials except where special functional requirements exist. Construction materials are resistant to the corrosive effect of process and decontamination fluids at the temperatures and pressures encountered.

- **Ventilation and Off-gas** - The building ventilation and process off-gas systems control the spread of airborne contamination through openings in barriers. By regulating the path of air or gas flow between these zones, gas leakage is directed from zones of low potential to zones of higher potential for contamination.

2.2.1 Natural Phenomena

The following natural phenomena are considered applicable to the CIF and are treated as design basis events:

- Earthquake
- Tornado
- Flooding

Other natural phenomena such as volcanic activity or tidal waves are not considered to be credible for the CIF site. Such events would be addressed in the future if warranted by the site selected for the facility. All safety class systems, structures, and components (SSCs) must withstand the consequences of all of these natural phenomena.

2.2.1.1 Earthquake. The design basis earthquake (DBE) for the CIF will be chosen in accordance with DOE-STD-1020-92 (UCRL-15910). All safety class systems, structures, and components are designed to withstand the DBE. Earthquakes exceeding the magnitude of the DBE are extremely unlikely accidents as defined in DOE-STD-3005-YR. Earthquakes of sufficient magnitude to cause the failure of safety class SSCs are considered incredible events as defined in DOE-STD-3005-YR.

2.2.1.2 Tornadoes. The design basis tornado (DBT) for the CIF will be chosen in accordance with DOE-STD-1020-92 (UCRL-15910). All processing and storage building structures housing plutonium and/or cesium, the Zone 1 exhaust system, and site effluent monitoring systems are designed to withstand the DBT and DBT-generated tornado missiles. Tornadoes exceeding the magnitude of the DBT are extremely unlikely accidents, as defined in DOE-STD-3005-YR. Tornadoes of sufficient energy to cause the failure of safety class SSCs are considered to be incredible events, as defined in DOE-STD-3005-YR.

2.2.1.3 Floods. Flooding is of particular concern at plutonium processing facilities such as the CIF because of the potential for nuclear criticality accidents. The CIF will be designed to preclude flooding of CIF areas that contain Pu. The design basis flood (DBF) for the CIF will be chosen in accordance with DOE-STD-1020-92 (UCRL-15910). All processing and storage building structures housing plutonium and/or cesium, the Zone 1 exhaust stack, site effluent-monitoring systems, and product canister storage vault racks in the canister storage building are designed to withstand the DBF. Floods exceeding the magnitude of the DBF are extremely unlikely accidents, as defined in

DOE Order 5480.24 also ranks, in order of preference, the different types of control that may be used to ensure criticality safety. Process designs are to rely on passive geometry controls whenever possible. When these are not possible, the order of preference is for other passive engineered controls, active engineered controls, and finally administrative controls.

ANSI/ANS-8.1 allows use of neutron absorbers for criticality control. Extreme care is required with solutions of absorbers because of the difficulty of exercising this type of control.

ANSI/ANS-8.1 requires that subcritical limits shall be established with adequate allowances for uncertainties. Methods of calculation used to determine k_{eff} for a system or used to establish subcritical limits shall be validated. The bias in the results shall be determined. The calculation shall incorporate sufficient margin to ensure subcriticality. The margin of subcriticality shall include allowances for the uncertainty in the bias.

No criticality analysis of the CIF has been done. The criticality issues for each stage of the ceramic immobilization process (including emplacement in a repository) are discussed below. These issues are assessed based on engineering judgment and extrapolation from similar processes. These assessments produce criticality safety assumptions used to size the facility. They also indicate that it will be possible to produce facility, process, material-handling, and waste-form designs that satisfy all applicable criticality safety requirements. However, all of these criticality safety assumptions and assessments require confirmation that can be provided only by a detailed criticality safety evaluation.

2.2.4.2 Plutonium Storage. The configuration of the CIF Pu storage vault is similar to that planned for the Special Isotope Separation (SIS) vault. The SIS design contains two planar arrays of pallets of approximately 800 storage locations. The pallets in each array are separated by 51 cm (20 in.) horizontally and by 61 cm (24 in.) vertically. Each storage position was assumed to contain a cylindrical button of pure ^{239}Pu metal. This design provides an adequate margin of subcriticality even with double batching of four central units, but it does not allow for flooding of the vault. The CIF requires storage for about 2,700 kg (5,900 lb) of Pu and PuO_2. The SIS vault would accommodate this inventory easily. Therefore, it is reasonable to assume that a design similar to that planned for SIS would be adequate for the CIF, provided that flooding is precluded. To meet this requirement, the design will need to address internal sources of water such as fire suppression systems and natural phenomena.

2.2.4.3 Plutonium Oxidation. The metal oxidation process at CIF is similar to the pyrochemical processes planned for SIS. The CIF processes approximately 7 kg (15.5 lb) of metal per day. The SIS conceptual design allowed plutonium metal batches as large as 3 kg (6.6 lb) (in the form of 11.4 cm [4.5-in.]-diam buttons with nominal reflection). Using the same batch size in the CIF, it is reasonable to assume that criticality considerations will not constrain the plutonium metal oxidation process at the CIF. Precise criticality controls and batch sizes will be specified as process requirements and geometries are established.

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confirmed by detailed analysis. Methods for controlling the Pu and Gd concentrations will be defined as the design evolves.

2.2.4.7 Ceramic Feed Storage. A 378.5-L (100-gal) hopper stores up to 420 kg (924 lb) of dry ceramic feed powder from the calciner. This means that the hopper contains about 50 kg (110 lb) of plutonium. It is assumed that the presence of gadolinium results in a safe configuration. The hopper geometry will be adjusted as required for safety. Multiple hoppers will be used if necessary. Controls on the plutonium concentration and inventory will be defined as the design evolves.

2.2.4.8 Bellows Pressing and Decontamination. The ceramic feed hopper fills individual bellows (30.5 cm [12 in.] diameter × 35.6 cm [14 in.] high). The hot press reduces the size of the bellows to 30.5 cm (12 in.) diam × 10.9 cm (4.3 in.) high, forming the ceramic. Each bellows contains approximately 33 kg (73 lb) of material. The composition is the same as the composition of the ceramic feed (see Sec. 2.2.4.6). Controls may need to be specified to ensure criticality safety for arrays of pressed bellows. Based on the requirements for the plutonium storage vault, it is assumed that 0.91-m (3.0-ft) center-to-center spacing is adequate provided that flooding can be precluded. The design will need to account for internal sources of water, such as fire suppression systems and natural phenomena.

2.2.4.9 Canister Filling, Decontamination, and Storage. Each 35.6-cm (14-in.)-diam by 243.8-cm (96-in.)-long canister contains 20 bellows containing about 12 percent plutonium homogeneously immobilized in the ceramic doped with a neutron absorber. This means that each canister contains approximately 80 kg (176 lb) of plutonium. Further, it is assumed that spacing the canisters on 1.52-m (5.0-ft) centers in the canister storage vault will be adequate to ensure safety, provided that flooding can be precluded. The Pu and Gd loading in the canister and the canister spacing will be adjusted as required for criticality safety.

2.2.4.10 Criticality Safety After Emplacement. It is necessary to ensure long-term criticality safety after the canister has been emplaced in the repository. At this point, it is assumed that brine intrusion and leaching are possibilities at some time in the future. It is also assumed that the long-term behaviors of the plutonium, the gadolinium, and the ceramic constituents are similar (i.e., that selective leaching of the neutron absorber, selective dissolution of the ceramic constituents and/or neutron absorber, and/or selective deposition of leached plutonium, are not credible processes). Given these conditions, it is assumed that it will be possible to provide enough gadolinium loading to ensure long-term criticality safety. The evaluation of the amount of gadolinium (samarium, hafnium, etc.) required will consider depletion by neutron capture. The Pu loading in the canister will be adjusted as required for safety.

2.2.4.11 Criticality Alarms. In cases where the mass of ^{239}Pu exceeds 450 g (15.9 oz) and the frequency of a nuclear criticality accident is greater than 10^{-6} per year, DOE Order 5480.24 requires that a criticality alarm system (CAS) meeting the requirements of ANSI/ANS-8.3 be provided to cover occupied areas in which the expected dose exceeds 12 rad in free air. At the CIF, this condition applies to the Pu preparation glovebox area and adjacent occupied areas. It also applies to occupied areas adjacent to the calciner feed mixing tank.

In cases where the mass of ^{239}Pu exceeds 450 g (15.9 oz) and the frequency of a nuclear criticality accident is greater than 10^{-6} per year, but the expected dose in occupied areas does not exceed .12 Gy (12 rad) in free air, DOE Order 5480.24 requires that a criticality detection system be provided. This condition does not exist at the CIF.

In cases where the mass of ^{239}Pu exceeds 450 g (15.9 oz) and the frequency of a nuclear criticality accident is less than 10^{-6} per year, DOE Order 5480.24 does not require a CAS. At the CIF, this condition applies to the plutonium storage vault, to the canister storage vault, and to areas that are not affected by the criticality accident postulated for the calciner feed mixing tank or the criticality accident postulated for the glovebox line.

2.2.5 Ventilation and Confinement

Confinement barriers and systems are selected in accordance with proven practices to perform the following functions:

- To limit the airborne spread of radioactive materials, the facility will be separated by confinement barriers into zones of various levels of contamination.
- The building ventilation and process off-gas systems will control the spread of airborne contamination through openings in barriers. By regulating the path of air or gas flow between these zones, gas leakage will be directed from zones of low potential to zones of higher potential for contamination.
- The capacity of the ventilation system (in relation to confinement system requirements) to ensure that the velocity of gas flowing through any barrier opening will be sufficient to prevent the backflow of airborne contaminants through such openings; air flow patterns must not be disrupted by winds, movement of equipment or personnel, or temporary opening of passageways through confinement barriers.
- Cooling water that could become contaminated by leakage of process solutions through defects in heat exchanger components will be contained in closed secondary circuits with independent primary heat transfer circuits. These circuits will be monitored for radioactivity.
- Steam with potential for contamination will be contained in a closed loop system. The condensate will be monitored and reused as feed to the process steam generator; contaminated condensate will be purged and flushed to the drain waste collection tank.
- Penetrations through confinement barriers that could provide potential pathways for release of radioactivity to the environment will have means for isolating the penetration such as airlocks at entrances to zones. Penetrations for wiring, piping, and instrumentation will be sealed to prevent backflow of radioactivity to normally occupied areas.
- Two types of confinement barriers will be used in the facility. "Total barriers" are those fabricated of material that prevent penetration of confined material

without regard to the physical or chemical nature. "Selective barriers" are mass transfer devices or filters to remove selected chemicals or particulate matter from a process or ventilation stream while allowing the bulk of the stream to pass.
- Barriers will be designed to withstand loadings due to pressure differentials imposed by the process off-gas, building ventilation systems, and natural phenomena.
- To monitor the integrity of total confinement barriers for gases, differential pressure monitors will be provided to indicate pressure differentials between confinement zones. To monitor total confinement barrier liquids, leakage will be detected by a liquid high-level alarm in a specially designated leakage collection sump. Leakage can also be measured by analytical devices that sound an alarm for contamination intrusion into normally uncontaminated tanks or process streams. Continuous air monitors will be used to indicate loss of function of a barrier, which could release radioactivity from a designated confinement area into an occupied area.
- Confinement systems will be constructed of nonflammable materials except where special functional requirements prohibit.
- Construction materials will be resistant to the corrosive effect of process and decontamination fluids at the temperatures and pressures encountered.
- Backup power will be provided to those confinement barriers and systems where loss of confinement could result from loss of primary electrical service.
- Standby fans will be provided to function for essential fans that may become inoperative.
- The confinement barriers will be designed to maintain functional integrity under the hypothesized major and DBAs where required.
- The confinement systems and components will be designed to allow maintenance to the system during operation.

2.3 Safeguards and Security

Protection of nuclear material involves both material control and accountability and physical security activities. Accountable nuclear materials include SNMs, source materials, and other nuclear material identified in DOE Order 5633.3A, *Control and Accountability of Nuclear Materials*. Integrated safeguards and security systems will effectively deter, prevent, detect, and respond to theft and diversion of nuclear material. In support of the U.S. nonproliferation policy, the DOE will make plutonium, that is surplus to the nation's defense requirements, available for verification and inspection by the International Atomic Energy Agency (IAEA).

The plutonium raw feed and ceramic product will be classified as special nuclear material according to DOE Order 5633.3A provisions for safeguards and security and material control. Accountability will be implemented to protect, control, and account for the materials at all times. Per Fig. I-2 of DOE Order 5633.3A the special nuclear material category dictates the level of security necessary to ensure appropriate protection of the material. From Fig. I-2 data, the raw plutonium feed and oxide will qualify as nuclear material safeguards Category I or II with a "B" or "C" Attractiveness Level depending on material form and quantity. The highly radioactive ceramic should qualify as Attractiveness Level E/Category IV material.

Special nuclear material classification is affected by the quantity of fissile material and the Attractiveness Level. The DOE defines the attractiveness level of nuclear material through a categorization of types and compositions that reflects the relative ease of processing and handling required to convert that material to a nuclear explosive device. Table 2-2 comes from the DOE Order for *Control and Accountability of Materials* (5632.33B) dated 9-7-94.

The level of protection accorded to an attractiveness level is dependent on the quantity or concentration of the material. Each category of protection has its own requirements ranging from the highest level of protection, Category I, for assembled weapons, to Category IV for irradiated forms and less than 3 kg (6.6 lb) of low-grade material. Protection of the material is accomplished through a graded system of deterrence, detection, delay, and response as well as material control and accountability. Layers of protection may then be applied to protect material of greatest attractiveness within the innermost layer and with the highest controls. Material of lesser attractiveness does not require as many layers of protection and fewer controls.

A "B" Attractiveness Level (the raw plutonium feed) represents material in the form of pits, major components, buttons, ingots, recastable metal, or directly convertible materials and is considered a "pure product" with the second highest security risk.

A "C" Attractiveness Level (the pretreated plutonium oxide) represents "high-grade" fissile materials in the form of carbides, oxides, solutions, nitrates, etc., fuel elements and assemblies, alloys and mixtures, uranium hexafluoride or uranium fluoride (≥ 50% enriched). For Special Nuclear Material Category I, Attractiveness Level B, ≥ 2 kg (4.4 lb) of Pu/^{233}U, or ≥ 5 kg (11 lb) of ^{235}U will be needed to qualify. For Category I, Attractiveness Level C, ≥ 6 kg (13 lb) of Pu/^{233}U or ≥ 20 kg (44 lb) of ^{235}U will be necessary.

The highest category, Attractiveness Level "D," represents material in Category II and is based on quantities ≥ 16 kg (35 lb) of Pu/^{233}U or ≥ 50 kg (110 lb) of ^{235}U.

Because of the high radiation levels of spent fuel and other Attractiveness Level "E" materials, theft or sabotage potential should be greatly reduced; and therefore, Categories I, II, or III rankings are not necessary for Level "E" material.

Table 2-2. (DOE) nuclear material attractiveness and safeguards categories for plutonium.

	Attractiveness Level	Pu/^{233}U category (Quantities in kg) I	II	III	IV[a]
WEAPONS Assembled weapons and test devices	A	All Quantities	N/A	N/A	N/A
PURE PRODUCTS Pits, major components, buttons, ingots, recastable metal, directly convertible materials	B	≥ 2 kg (4.4 lb)	≥ 0.4 < 2 kg (≥ 0.9 ≥ 4.4 lb)	≥ 0.2 < 0.4 kg (≥ 0.4 < 0.9 lb)	< 0.2 kg (< 0.4 lb)
HIGH-GRADE MATERIAL Carbides, oxides, solutions (≥ 25 g/L) nitrates, etc., fuel, elements and assemblies, alloys and mixtures, UF_4 or UF_6 (≥ 50% ^{235}U)	C	≥ 6 kg (≥ 13 lb)	≥ 2 < 6 kg (≥ 4.4 < 13 lb)	≥ 0.4 < 2 kg (≥ 0.9 < 4.4 lb)	< 0.4 kg (< 0.9 lb)
LOW-GRADE MATERIAL Solutions (1 - 25 g/L), process residues requiring extensive reprocessing, moderately irradiated material, ^{238}Pu (except waste), UF_4 or UF_6 (≥ 20% < 50% ^{235}U)	D	N/A	≥ 16 kg (≥ 35 lb)	≥ 3 < 16 kg (≥ 6.6 < 35 lb)	< 3 kg (< 6.6 lb)
ALL OTHER MATERIALS Highly irradiated forms, solutions (≥ 1 g/L), uranium containing < 20 % ^{235}U (any form or quantity)	E	N/A	N/A	N/A	Reportable quantities

[a] The lower limit for category IV is equal to reportable limits in this Order

Although the CIF may have several categories of SNM onsite at any given time, the most conservative classification for design and overall facility safeguards and security will be Category I, Attractiveness Level "B" while specific areas of the facility could be designed to other category or attractiveness levels as noted in the preceding paragraphs. Consequently, the facility requirements for the protection of safeguards and security interests originate from appropriate Special Nuclear Material Category I criteria outlined in DOE Order 5632.1C, *Protection and Control of Safeguards and Security Interests,* the DOE M 5632.1C-1, *Manual for Protection and Control of Safeguards and Security Interests*, and other applicable DOE Orders. For the CIF, general safeguards and security requirements are described below.

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- Domestic off-site shipments of Category I Special Nuclear Material are governed by the transportation safeguards system under the auspices of the Albuquerque Operations Office.
- Packages or containers containing special nuclear material will be sealed with tamper-indicating devices.
- Protection measures for movement of material between protected areas onsite and between protected areas and staging areas will be under direct surveillance by the security officers to protect against threats established by site policy.

2.3.1.3 Intrusion Detection and Lighting. Intrusion detection systems will be installed to provide reasonable assurance that breaches of security boundaries are detected, and that intrusion information is provided to security personnel. Intrusion detection systems will also be provided for vaults and vault-type rooms. Twenty-four-hour protective lighting will be provided to permit detection and assessment of adversaries and to reveal unauthorized persons.

2.3.1.4 Access Control and Entry/Exit Inspections. Access is restricted to personnel with a need to enter the protected area and material access Area. At routine exits from material access areas, metal detectors, special nuclear material monitors, explosive detectors, and x-ray machines will be used to conduct inspections for prohibited articles and government property. Data and equipment access controls are applied on a graded basis. In addition to DOE Order 5633.3A, access controls may be governed by the DOE requirements for the control of classified documents and for computer security.

2.3.1.5 Barriers and Locks. Physical barriers such as fences, walls, doors, or activated barriers will be used to delay unauthorized access to security areas. Physical barriers will serve as the physical demarcation of the security area. When used for protection purposes, fencing will meet the construction requirements of DOE Order 6430.1A. Locks used in the protection of classified matter and Categories I and II SNM (e.g., security containers, safes, vaults) will meet Federal Specification FF-L-2740, Locks, Combination, or Military Specification MIL-P-43607, Padlock, Key Operated, High Security, Shrouded Shackle.

2.3.1.6 Vaults and Vault-Type Rooms. Most Category I materials are stored in vaults or vault-type rooms. These rooms are equipped with approved intrusion alarm systems, and two authorized Q-cleared employees will be present to gain access to Category I storage locations. Security devices assure the presence of two people. Most facilities use two combination locks. Each lock has a unique combination and access list. Nobody assigned to the vault has the combination to both locks. Facility personnel maintain lists of employees who may access storage areas, and security forces receive a copy of these lists. Security inspectors stationed in the central alarm station verify the presence of two authorized persons before granting access. Facility personnel update the access lists quarterly, and facility-specific procedures contain directions for accessing vaults and vault-type rooms. The minimum standards required for construction of SNM storage vaults other than modular vaults are detailed in DOE

Order 6430.1A, *General Design Criteria*, and apply to new construction, reconstruction alterations, modifications, and repairs.

2.3.1.7 Communications. Communications equipment will be provided to aid in reliable information exchange between security personnel. The equipment must have two different technologies of voice communications to link the facility with each fixed post, central alarm station, secondary alarm station (SAS), and protected personnel dispatch point. Backup or alternative communications capabilities will be readily available upon failure of the primary communications system.

2.3.1.8 Acceptance and Validation Testing. Acceptance and validation tests are performed to confirm the ability of an implemented and operating system or element to meet an established protection requirement. Two levels of tests will be addressed in the overall safeguards and security acceptance and validation test program.

2.3.1.9 Maintenance. Security-related subsystems and components will be maintained in operable condition per the DOE 4330.4B, *Maintenance Management Program*.

2.3.1.10 Posting Notices. Selection of facilities, installations, and real property for posting of signs will be based upon need for protecting against espionage, sabotage, or depredation of safeguards and security interests.

2.3.1.11 Security Badges. Security badges shall indicate individuals access limitations and/or approvals for the purpose of controlling entrance and exit to security areas and facilities and for safeguards and security-related identification purposes.

3.0 Site Map and Land Use Requirements

3.1 Site Map

The CIF site map is shown in Fig. 3-1. The site is surrounded by multiple fences for security. The main processing facilities are located within a double security fence and include the Plutonium Processing Facility, the adjacent Radwaste Management Building, Hot Maintenance Shop, and Product Canister Storage Building. Support facilities including the Administration Building, Warehouse, Shops and Equipment Mock-up Building, Support Utilities Building, Cooling Tower and Electrical Substation. The Industrial Waste Treatment Building and the Sanitary Waste Treatment Facility are located outside the security area, but within the overall site perimeter fence.

Access to the site is controlled at guardhouses located at both the perimeter fence and at the security fence surrounding the process area. A ventilation exhaust stack discharges process and ventilation air from the Plutonium Processing Building, the Radwaste Management Building, the Canister Storage Building, and the Hot Maintenance Shop. Other sources of airborne emissions from the site are the boiler stack at the Support Utilities Building and HVAC exhaust outlets from the nonprocess support buildings outside the security fence. All liquid effluents from the site are from either the Industrial Waste Treatment Facility or the Sanitary Waste Treatment Facility.

3.2 Land Area Requirements during Operation

The overall site occupies approximately 12 hectare (30 acres) during operation.

3.3 Land Area Requirements during Construction

Land area requirements during construction (as shown in Fig. 3-2) are approximately 20 hectare (50 acres); this will include the necessary area for construction activities, including the following:

- Construction laydown area for temporary storage of construction materials such as structural steel, pipe, lumber for concrete forms, and electrical conduit.
- Temporary construction offices for housing onsite engineering support, construction supervision and management personnel.

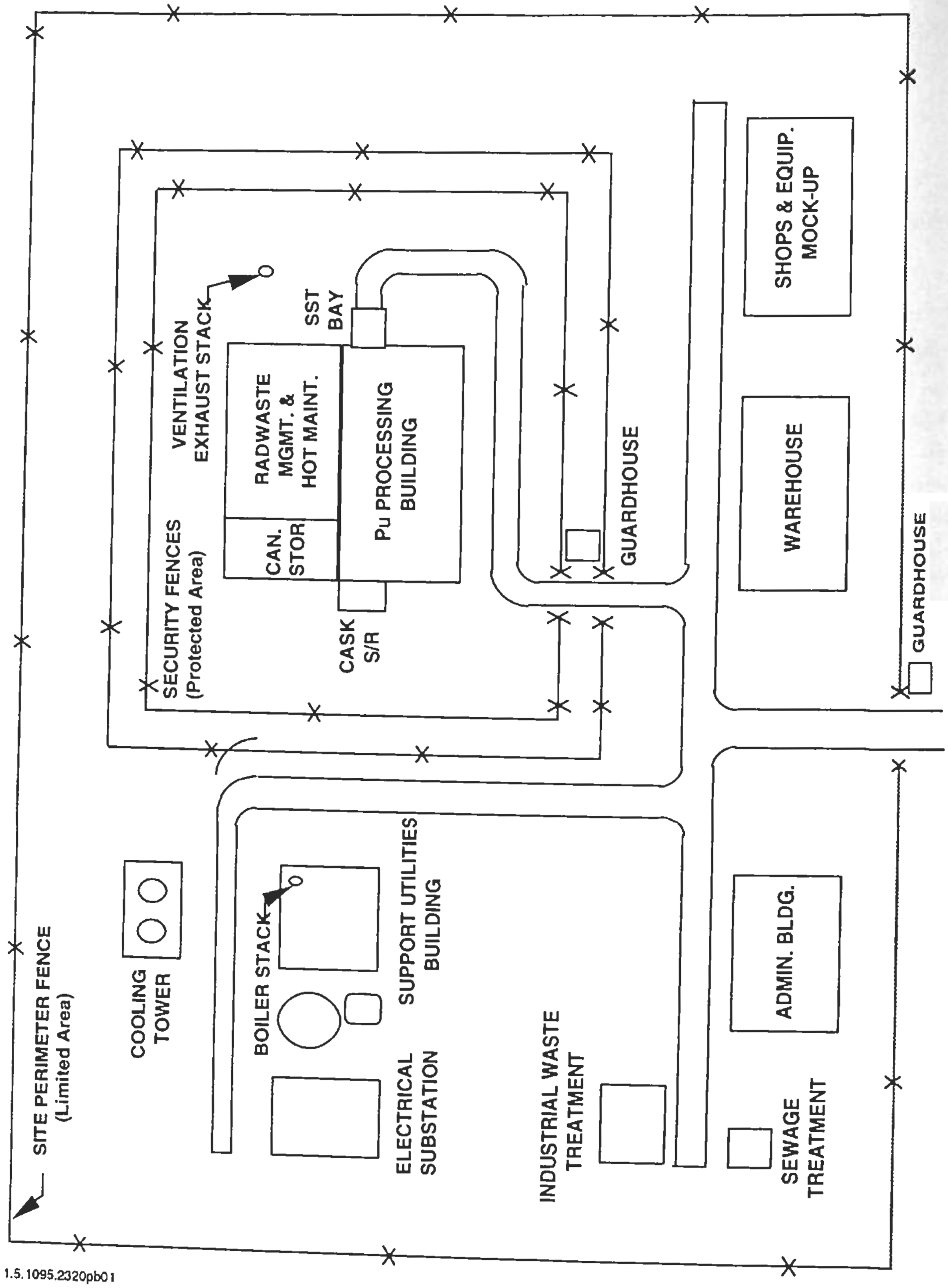

Figure 3-1. Site map.

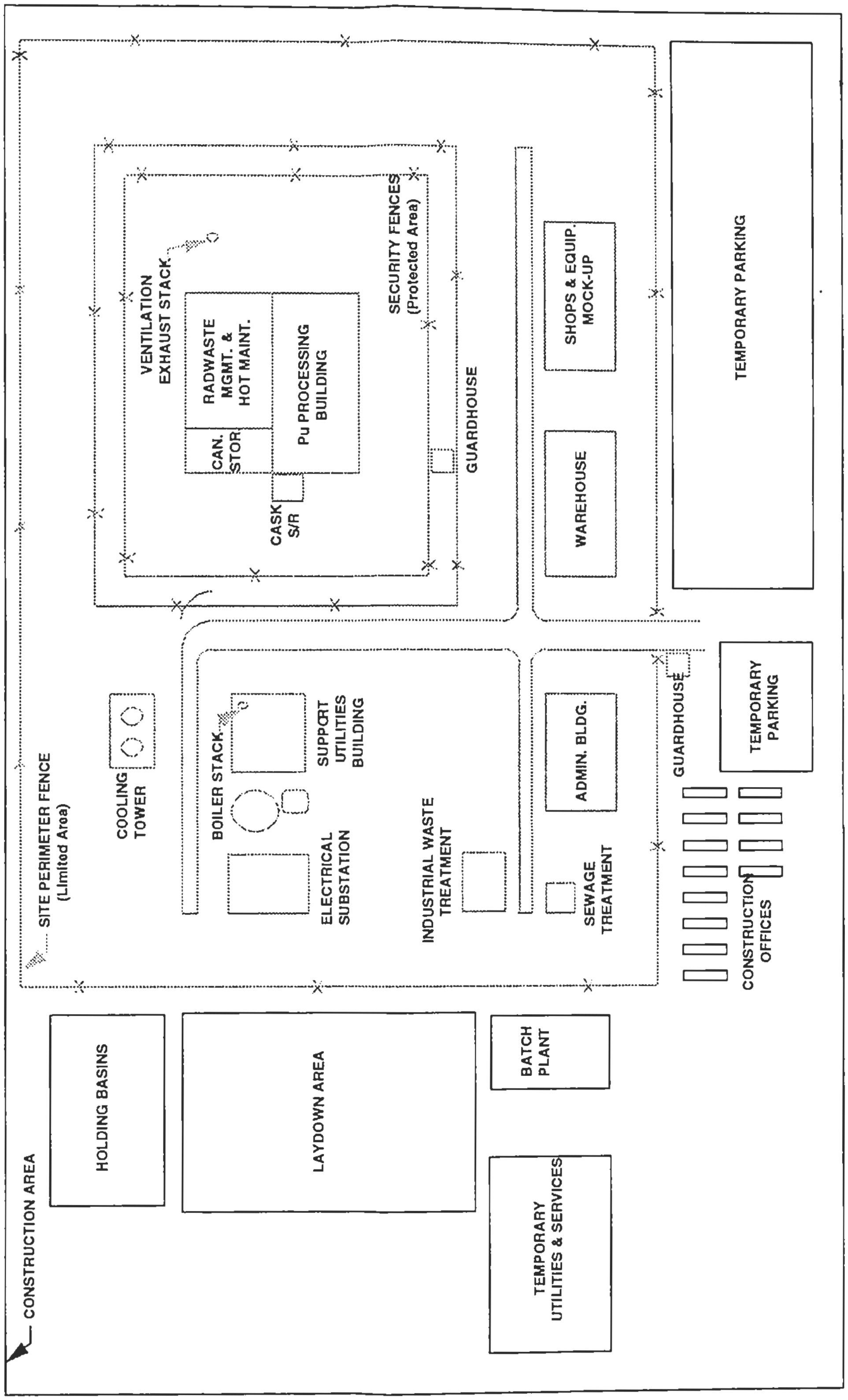

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Figure 3-2. Site map during construction.

- An onsite concrete batch plant to produce the concrete required for the major facility buildings and structures.
- Temporary parking for construction craft workers and support personnel.
- Temporary holding basins for controlling surface water runoff during construction.
- Area for installing required temporary utilities and services, including construction service water, sanitary facilities, electrical power, and vehicle fuel.

Note that the estimated construction area is based on a generic site (Kenosha, WI) and will require adjustment for the actual site selected.

4.0 Process Descriptions

Plutonium is immobilized with ^{137}Cs spiking in a titanate based ceramic. The main processing steps are:

- Plutonium Metal Oxidation
- Plutonium Oxide Dissolution
- Ceramic Precursor/Nuclear Absorber Addition
- Calcination
- Bellows Filling
- Hot Pressing
- Canister Loading

A simplified block flow diagram of the ceramic immobilization process is shown in Fig. 4-1.

4.1 Plutonium Oxidation and Dissolution

4.1.1 Plutonium Oxidation and Dissolution Function

Figure 4-2 depicts the Pu feed preparation.

Plutonium metal ingots and plutonium oxide are received in shipping containers. The containers of plutonium are unpacked and identified by bar code, and seal integrity is verified. Confirmatory and accountability measurements are made as necessary. The containers are stored in a plutonium vault.

Plutonium metal is removed from storage and sent via a conveyor system to a dry nitrogen-atmosphere glovebox for shearing and size reduction as necessary for the oxidation process. The metal is oxidized with air in a furnace at about 650°C (1200°F). The material is stirred to promote oxidation and ensure complete reaction. The off-gas is filtered to remove particulates, which are combined with the oxide product.

The plutonium oxide is transferred to an air-atmosphere glovebox and charged batchwise to a mediated electrochemical oxidation (MEO) dissolver, which contains a nitric-acid/silver-nitrate solution. The oxidizing agent is silver (II) ion (Ag^{2+}), which is generated electrolytically in the dissolver system. Off-gas includes NO_x and water vapor. The dissolution product is a solution of plutonyl nitrate ($PuO_2(NO_3)_2$) in 4*M* (molar) nitric acid and 0.1*M* silver nitrate. The product is transferred to storage tanks, where a liquid sample is taken for analysis and accountability. The MEO dissolver and plutonyl nitrate storage tanks are a geometrically favorable design.

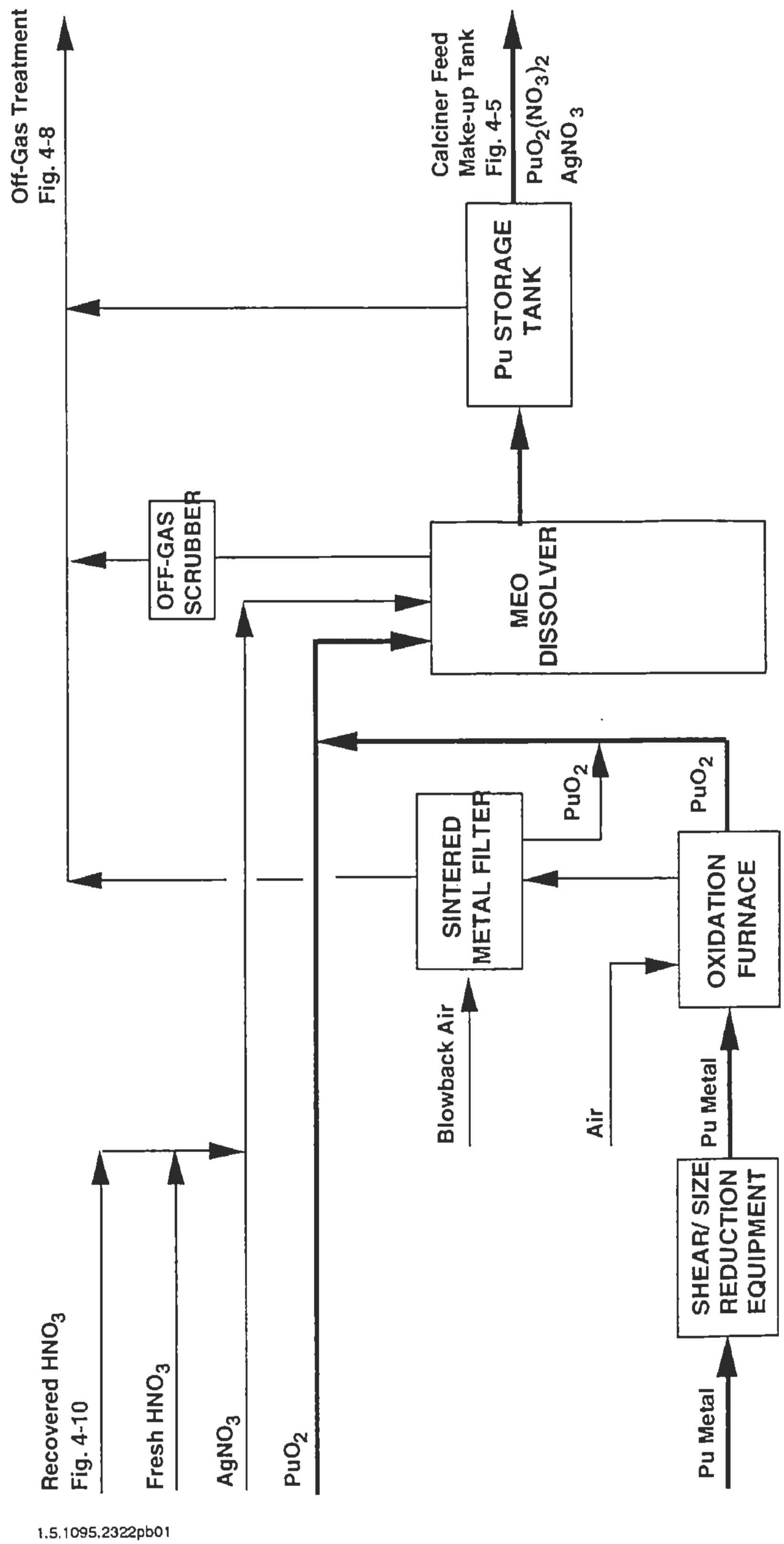

Figure 4-2. Plutonium feed preparation.

Plutonium oxide feed is processed in the same way, except that the oxidation step is not required. About 25 kg (55 lb) of Pu are processed per day. The oxide dissolution rate is ~1.1 kg/hr (2.4 lb/hr). About 126 L (33.3 gal) of 200 g Pu/L (26.7 oz Pu/gal) solution is produced per day.

Handling of plutonium metal, oxide, and solutions, as well as the oxidation process are routine and well-established operations. Laboratory-scale MEO dissolvers have been operated extensively, and production scale units have been designed and tested.

4.1.2 Plutonium Oxidation and Dissolution Feeds

The feeds are plutonium metal, plutonium oxide, nitric acid (fresh and recycled), and silver nitrate.

4.1.3 Plutonium Oxidation and Dissolution Products

Products are plutonyl nitrate ($PuO_2(NO_3)_2$) in 4*M* nitric acid and 0.1*M* silver nitrate.

4.1.4 Plutonium Oxidation and Dissolution Utilities Required

Utilities required include electrical power for the oxidation furnace, MEO dissolver, instrumentation, and ventilation. Also needed are sources of nitrogen for glovebox atmospheres and air for oxidation furnace and filter blowback.

4.1.5 Plutonium Oxidation and Dissolution Chemicals Required

Chemicals required are nitric acid and silver nitrate.

4.1.6 Plutonium Oxidation and Dissolution Special Requirements

Facilities and equipment to safely handle plutonium metal and oxide in accordance with applicable DOE/NRC orders and regulations provide safeguards against criticality and diversion of plutonium. Care must be taken to guard against exposure of personnel to plutonium metal or oxide and preclude ignition of plutonium metal except under controlled conditions. Processes will be carried out in glovebox enclosures.

4.1.7 Plutonium Oxidation and Dissolution Waste Generated

Off-gases include NO_x and water vapor. Waste includes used ventilation air filters and contaminated operator clothing, gloves, wipes, shoe covers, process equipment, and tools.

4.2 Cesium Capsule Processing

4.2.1 Cesium Capsule Processing Function

Figure 4-3 is the process flow diagram for cesium conversion.

Cesium is assumed to be received in the form of CsCl capsules from Hanford. The cesium is contained in double-walled, stainless-steel capsules with outside dimensions of 6.67 cm (2.6 in.) in diameter by 52.77 cm (21.0 in.) long. The question of whether there is enough cesium in the Hanford capsules alone to accomplish the immobilization mission is being evaluated.

Cesium processing is conducted in a shielded cell with manipulators and shield windows. One capsule is processed at a time. The outer capsule is cut open, decontaminated, and discarded as low-level waste (LLW). The inner capsule is then sheared to expose the cesium and barium chloride solids. The sheared pieces are leached in hot water and agitated to dissolve the solid salts. The solution is transferred to the ion exchange feed tank. Finally, the capsule hull is decontaminated and disposed of as LLW.

The chloride is loaded onto the cation exchange column, and the effluent contains chlorides and exchanged cation. The product solution is stored in a tank, which may need cooling coils to remove decay heat. The effluent, which contains chlorides and exchanged cation, is recycled to the column as necessary to remove residual cesium. Finally, the effluent is neutralized and sent to waste treatment for solidification as LLW.

This method of processing cesium is similar to techniques used to process spent nuclear fuel.

4.2.2 Cesium Capsule Processing Feeds

The feed is CsCl in capsules, which also contain the ^{137}Cs daughter product barium chloride. Because of the change in oxidation state, it is assumed that 50% of the barium is present as $BaCl_2$ and 50% is present as barium metal.

4.2.3 Cesium Capsule Processing Products

Products are cesium nitrate and barium nitrate in solution.

4.2.4 Cesium Capsule Processing Utilities Required

Utilities required include electrical power for remote handling equipment, process equipment, instrumentation, and ventilation. Also needed are sources of water for process and capsule decontamination and cooling.

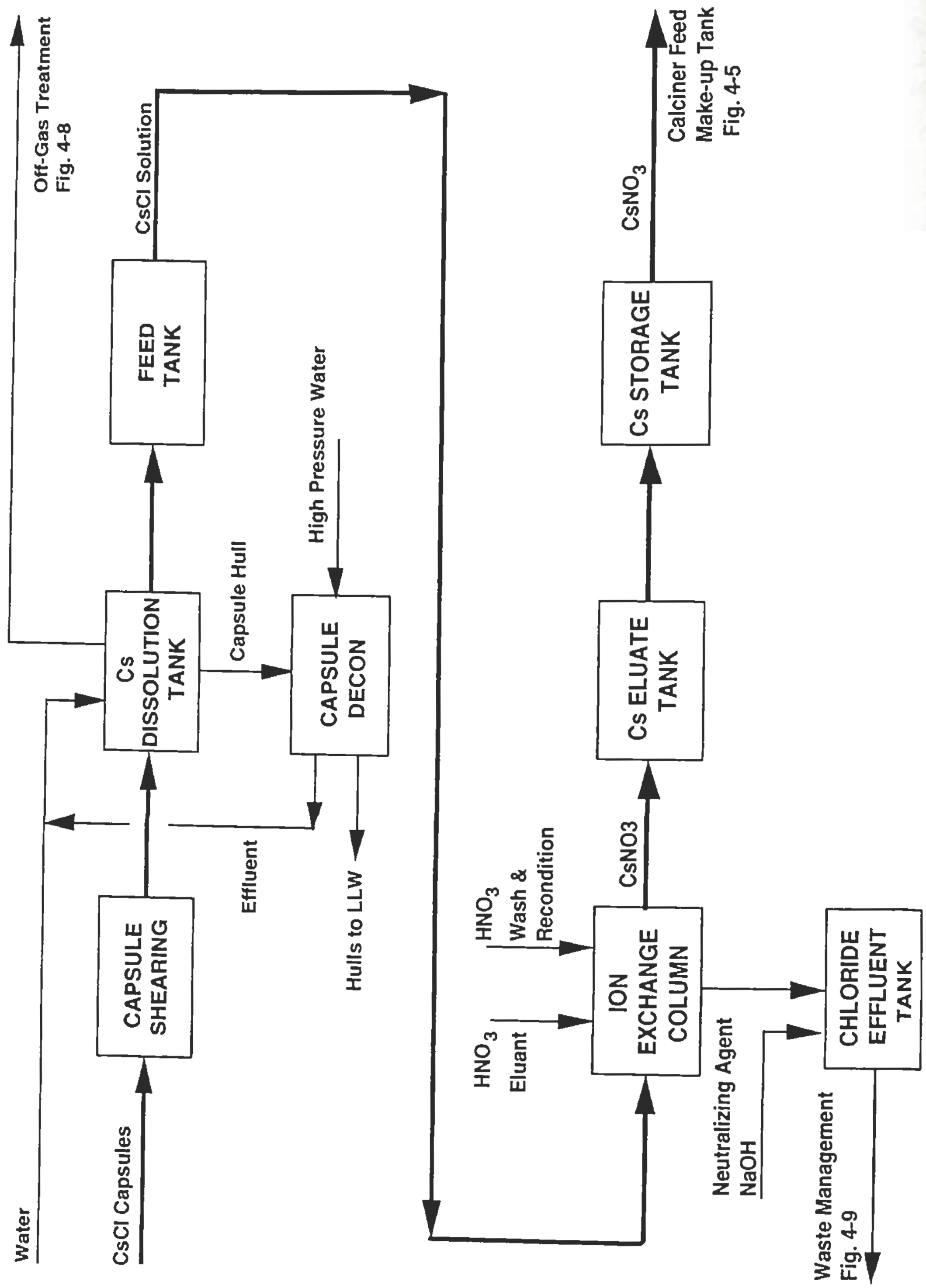

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Figure 4-3. Cesium conversion process flow diagram.

4.2.5 Cesium Capsule Processing Chemicals Required

Chemicals needed include nitric acid, sodium hydroxide, and ion exchange resin.

4.2.6 Cesium Capsule Processing Special Requirements

Processing must take place in a heavily shielded cell. Manipulators are used to protect workers from exposure to highly radioactive cesium.

4.2.7 Cesium Capsule Processing Waste Generated

Waste includes contaminated capsule hulls, spent ion exchange resin, neutralized chloride waste solution, and dissolution tank off-gas.

4.3 Ceramic Precursor and Neutron Absorber Preparation

4.3.1 Ceramic Precursor Preparation Function

Figure 4-4 is the process flow diagram for preparing the ceramic precursor (ceramic-forming ingredients).

Ceramic precursor solids are assumed to have been formulated and premixed by a chemical vendor.

Dry precursor is weighed and mixed with a measured amount of demineralized water in a precursor mix tank. The tank contents are thoroughly mixed to eliminate agglomerates and to produce a well-dispersed slurry. The slurry is pumped to the calciner feed makeup tank inside the shielded cell.

Dry gadolinium nitrate hexahydrate is weighed and mixed with water in a mix tank. The tank contents are agitated to dissolve the solid gadolinium compound. After sampling, the solution is pumped to the calciner feed makeup tank.

4.3.2 Ceramic Precursor Preparation Feeds

Feeds are ceramic precursor (TiO_2, ZrO_2, Al_2O_3, BaO, CaO), gadolinium nitrate hexahydrate, and demineralized water.

4.3.3 Ceramic Precursor Preparation Products

Products are a slurry of ceramic precursor in water and Gd $(NO_3)_3$ in solution.

4.3.4 Ceramic Precursor Preparation Utilities Required

Utilities needed include electrical power for mixing equipment, grinder, instrumentation, and ventilation.

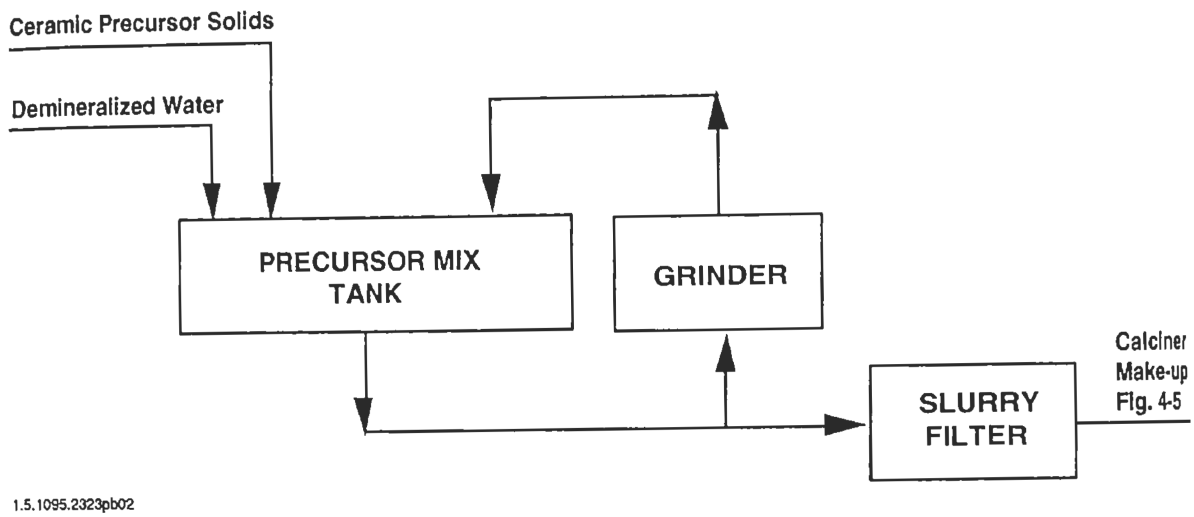

Figure 4-4. Ceramic precursor makeup process flow diagram.

4.3.5 Ceramic Precursor Preparation Chemicals Required

No chemicals are needed other than the feed materials.

4.3.6 Ceramic Precursor Preparation Special Requirements

There are no special requirements other than normal industrial practice in accordance with OSHA standards.

4.3.7 Ceramic Precursor Preparation Waste Generated

Waste consists of uncontaminated empty precursor containers.

4.4 Feed Preparation And Calcination

4.4.1 Feed Makeup and Calcination Function

Figure 4-5 is the process flow diagram for mixing and calcination.

The calciner feed makeup tank receives the ceramic precursor slurry and the plutonium, neutron absorber, and cesium solution. Bottoms from the recycle waste evaporator are also received. The slurry is mixed, sampled, and then pumped to the calciner feed tank.

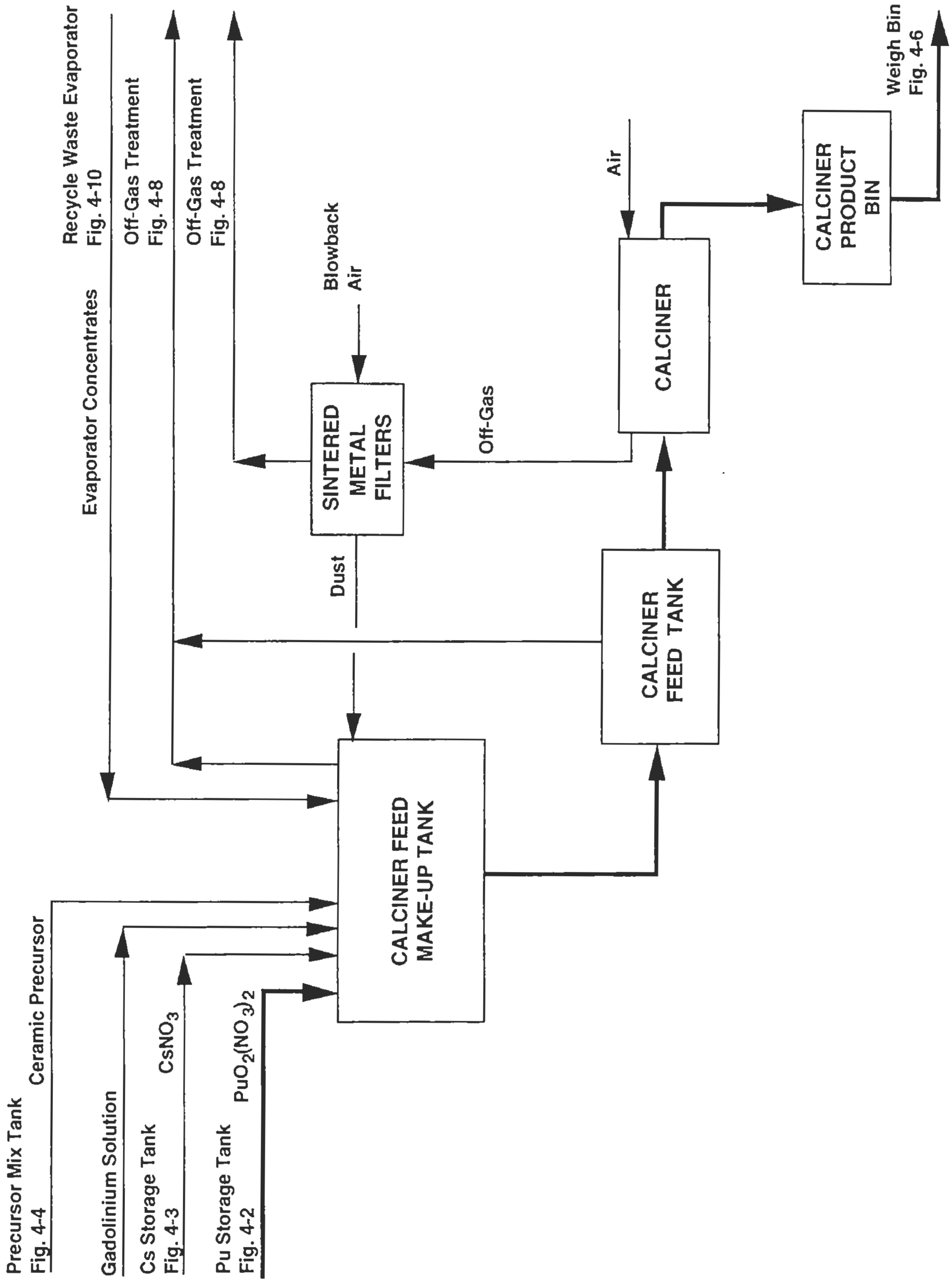

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Figure 4-5. Mixing and calcination process flow diagram.

It is assumed that the makeup and feed tanks and all other downstream equipme are not required to be critically safe by geometry, because the gadolinium neutron absorber is mixed uniformly in the slurry.

The gadolinium absorber is assumed to be soluble solid gadolinium nitrate hexahydrate. The absorber must be soluble to ensure that loss of agitation does not cause the absorber to settle in a process tank. The solution in the calciner feed tank is pumped to the calciner at a controlled rate. The rotary calciner design is based on one now operating at the ANSTO demonstration plant. The calciner is an electrically heat rotary kiln with multiple heating zones. The calciner feed first enters the drying zone where water is driven off and a dry solid is produced. The solid flows down the calci tube to the denitration and calcining zone operating at 750°C (1,380°F), where the oxi are formed. Off-gas includes water vapor, nitrous oxides, and carbon dioxide. The ho dry powder discharges into the calciner product bin.

Off-gas from the calciner enters a sintered metal filter vessel, which removes most the dust from the off-gas. The filter elements are periodically blown back with air to dislodge the dust, which is collected and recycled to the feed tank.

4.4.2 Feed Makeup and Calcination Feeds

Feeds consist of plutonyl nitrate solution, ceramic precursor slurry, cesium nitrate solution, gadolinium neutron absorber solution, and bottoms from the recycle waste evaporator.

4.4.3 Feed Makeup and Calcination Products

Products include calcined powder comprised of ceramic-forming minerals (including plutonium, cesium, and gadolinium).

4.4.4 Feed Makeup and Calcination Utilities Required

Utilities required are electrical power for feed mixing, calciner, instrumentation, a ventilation and air for calciner purging and filter blowback.

4.4.5 Feed Makeup and Calcination Chemicals Required

No chemicals are required other than the feed materials.

4.4.6 Feed Makeup and Calcination Special Requirements

Facilities and equipment are required to safely handle plutonium oxide in accordance with applicable DOE/NRC orders and regulations and to guard against diversion of plutonium. Care must be taken to guard against exposure of personnel to plutonium oxide. Processing must take place in a heavily shielded cell using manipulators to protect workers from exposure to highly radioactive cesium.

4.4.7 Feed Makeup and Calcination Waste Generated

Waste consists of off-gases, including water vapor, nitrous oxides, carbon dioxide, and some dust containing plutonium and cesium. Solid waste includes used ventilation air filters and contaminated operator clothing, gloves, wipes, shoe covers, and process equipment.

4.5 Bellows Filling and Closure

4.5.1 Bellows Filling and Closure Function

Figure 4-6 is the process flow diagram for filling and pressing.

After sampling, a calculated amount of powder from the calciner product bin is transferred to the powder weigh bin by screw conveyor. The calcine powder is mixed with titanium metal powder in the weigh bin. The titanium is used for valence control during processing. A manipulator is used to place an empty bellows in the bellows filling machine. The bellows fill opening is sealed to the weigh bin discharge to prevent dusting and powder is metered into the bellows. The bellows is vibrated to compact the material. After filling, the bellows is moved to the sealing station, and the fill port is plugged. The bellows is moved to the bellows decontamination station, where the exterior of the bellows is cleaned with high-pressure water and brushes. This minimizes contamination of the hot press. The decontamination effluent is transferred to the recycle waste evaporator.

Each bellows contains 33 kg (72.6 lb) of powder, including 4 kg (8.8 lb) of Pu and 50 g (1.76 oz) of Cs. A bellows is about 300 mm (11.8 in.) in diameter by 350 mm (13.78 in.) high (uncompacted).

4.5.2 Bellows Filling and Closure Feeds

Feeds include calcined ceramic-forming powder, empty bellows, and bellows lids.

4.5.3 Bellows Filling and Closure Products

Products consist of filled bellows containing 33 kg (72.6 lb) of powder, including 4 kg (8.8 lb) of Pu. A bellows is about 300 mm (11.8 in.) in diameter by 350 mm (13.78 in.) high.

4.5.4 Bellows Filling and Closure Utilities Required

Utilities required include electrical power for screw conveyor, weighing equipment, manipulator, sealing equipment, instrumentation, and ventilation. Also needed are sources of water for bellows decontamination and air for filter blowback.

4.5.5 Bellows Filling and Closure Chemicals Required

Titanium metal powder is the only chemical required.

4.5.6 Bellows Filling and Closure Special Requirements

Special requirements exist for facilities and equipment to safely handle plutonium oxide in accordance with applicable DOE/NRC orders and regulations and to guard against diversion of plutonium. Care must be taken to guard against exposure of personnel to plutonium oxide in this operation, which potentially can generate fine dust. Processing must take place in a heavily shielded cell. Manipulators are used to protect workers from exposure to highly radioactive cesium.

4.5.7 Bellows Filling and Closure Waste Generated

Bellows filling and closure produce potentially contaminated air from weigh bin (air passes through sintered metal filters prior to release to off-gas treatment), contaminated water from bellows decontamination, used ventilation air filters, and contaminated operator clothing, gloves, wipes, shoe covers, and process equipment.

4.6 Hot Pressing

4.6.1 Hot Pressing Function

The filled bellows is transferred to a preheat furnace, where it is heated to 1150°C (2100°F) in 5 to 6 hr. The bellows is then transferred to the hot press furnace, where it is hot pressed at about 1150°C (2100°F) and 14 MPa (~2000 psi) for 2 hr. During the hot pressing, the diameter of the bellows remains relatively unchanged, but the height decreases by about one-third. The pressed bellows is transferred to an insulated box for a controlled cooldown.

Hot pressing is used at the Australian Nuclear Science Technology Organisation (ANSTO) demonstration plant to produce Synroc material (surrogate material without radioactivity) for HLW applications.

4.6.2 Hot Pressing Feeds

Feed consists of bellows filled with ceramic-forming powder.

4.6.3 Hot Pressing Products

Product is compressed bellows containing ceramic product.

4.6.4 Hot Pressing Utilities Required

Electrical power is required for preheating oven, hot press, instrumentation, and ventilation.

4.6.5 Hot Pressing Chemicals Required

None.

4.6.6 Hot Pressing Special Requirements

Facilities and equipment to safely handle plutonium oxide in accordance with applicable DOE/NRC orders and regulations and to guard against diversion of plutonium. Care must be taken to guard against exposure of personnel to plutonium oxide in this operation which has the potential for generating fine dust in the event of a bellows failure. Processing must take place in a heavily shielded cell. Manipulators are used to protect workers from exposure to highly radioactive cesium.

4.6.7 Hot Pressing Waste Generated

Waste includes off-gas from pressing. Solid waste consists of used ventilation air filters and contaminated operator clothing, gloves, wipes, shoe covers, and (potentially) process equipment.

4.7 Canister Loading

4.7.1 Canister Loading Function

Figure 4-7 is the process flow diagram for canister loading and handling.

After cooling, the compacted bellows are loaded into a metal canister [35 cm (14 in.) in diameter by 2.4 m (8 ft) high], and a packing material such as TiO_2 powder is added. After 20 bellows are loaded into the canister, the canister is moved to the canister welding station. A helium capsule is placed in the canister, and a lid is welded on to seal the canister. The canister is moved to the leak test station, where a helium leak test is performed.

The loaded canister is then placed in the canister decontamination station, where the canister exterior is decontaminated with high-pressure water. The decontamination effluent is transferred to the recycle waste evaporator. After compressed-air drying, the canister is moved to the canister smear test station, where the exterior of the canister is swiped with paper test swabs. The test swabs are placed in a pneumatic transfer unit and transferred to an analytical laboratory outside the shielded cell, and counted for radioactivity. If the smearable contamination is above limits, the canister is recleaned and smear-tested again.

The loaded canister is assayed to determine the plutonium content. The canister is transferred to the storage facility, where it is stored until it is loaded into a shipping container and onto a truck or rail car for transport to its final disposition.

Remote welding, leak testing, decontamination, and smearing of canisters have been developed in HLW immobilization research programs in the United States and abroad.

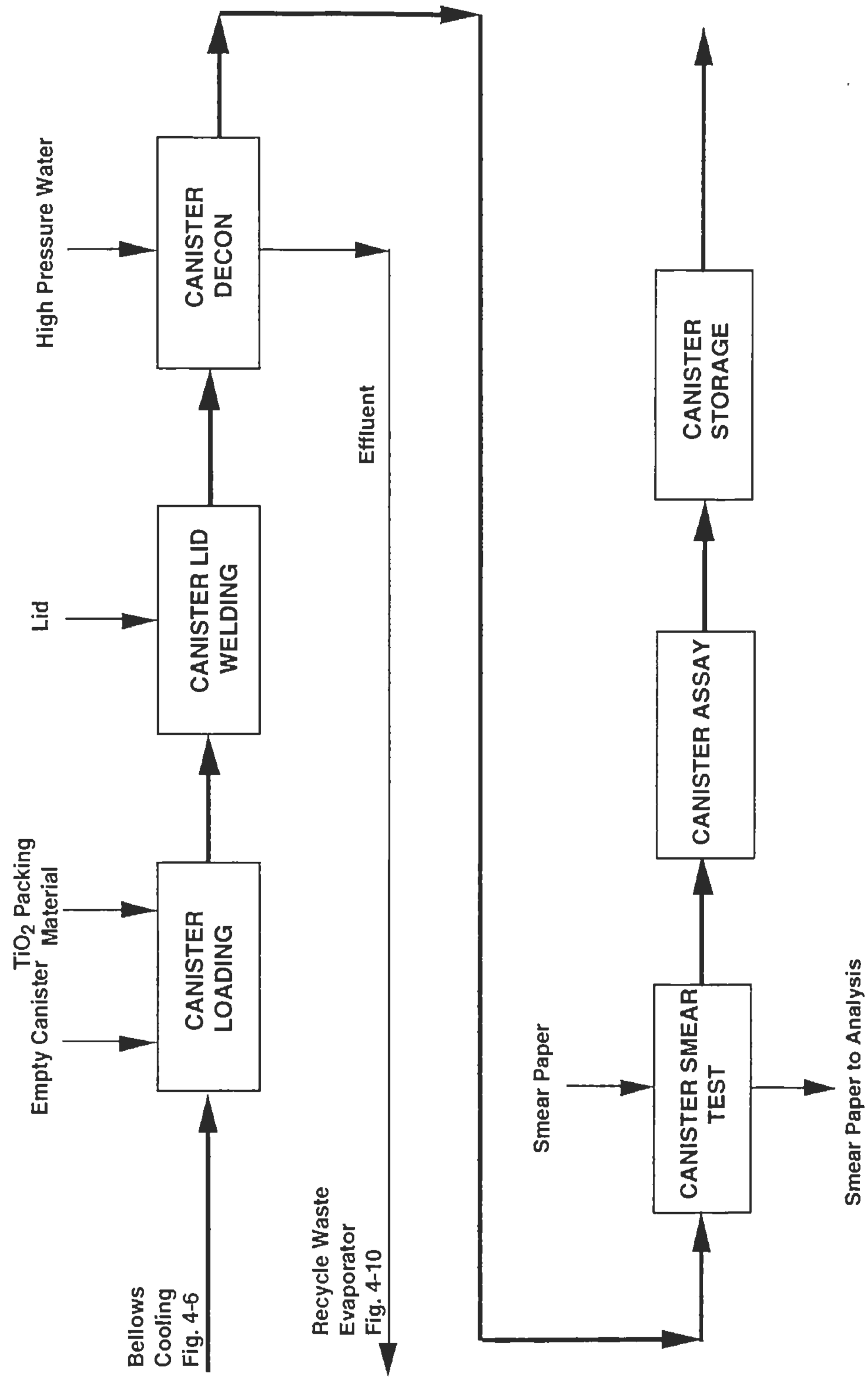

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Figure 4-7. Canister loading and handling process flow diagram.

4.7.2 Canister Loading Feeds

Feeds consist of compressed bellows, empty canisters, and canister lids.

4.7.3 Canister Loading Products

Products are filled, sealed canisters.

4.7.4 Canister Loading Utilities Required

Electrical power is required for canister welding equipment, canister transfer equipment, instrumentation and test equipment, and ventilation. Water is required for canister decontamination, air for canister drying.

4.7.5 Canister Loading Chemicals Required

TiO_2 powder is required for packing and helium test capsules.

4.7.6 Canister Loading Special Requirements

Facilities and equipment are needed to safely handle plutonium in accordance with applicable DOE/NRC orders and regulations and to guard against diversion of plutonium. Equipment for handling loaded canisters may need to be specially designed Processing must take place in a heavily shielded cell with manipulators used to protect workers from exposure to highly radioactive cesium.

4.7.7 Canister Loading Waste Generated

Potential waste includes contaminated water. Solid waste will include used ventilation air filters (potentially) process equipment, operator clothing, gloves, wipes, and shoe covers.

4.8 Process Off-gas System

4.8.1 Process Off-gas System Function

Figure 4-8 shows the process off-gas system.

Off-gas from the hot press and calciner enters a condenser to condense the steam and cool the off-gas. Off-gas from the condenser and process tank vents then flows through a heater, HEPA filter, and an NO_x absorption column. Urea is added to the scrub solution tank to convert some of the absorbed NO_x to nitrogen. Most of the remainder of the NO_x forms nitric acid. The off-gas then flows through another heater and HEPA filter and discharges to the HVAC exhaust containing three HEPA filters in series and is then discharged to atmosphere through a stack.

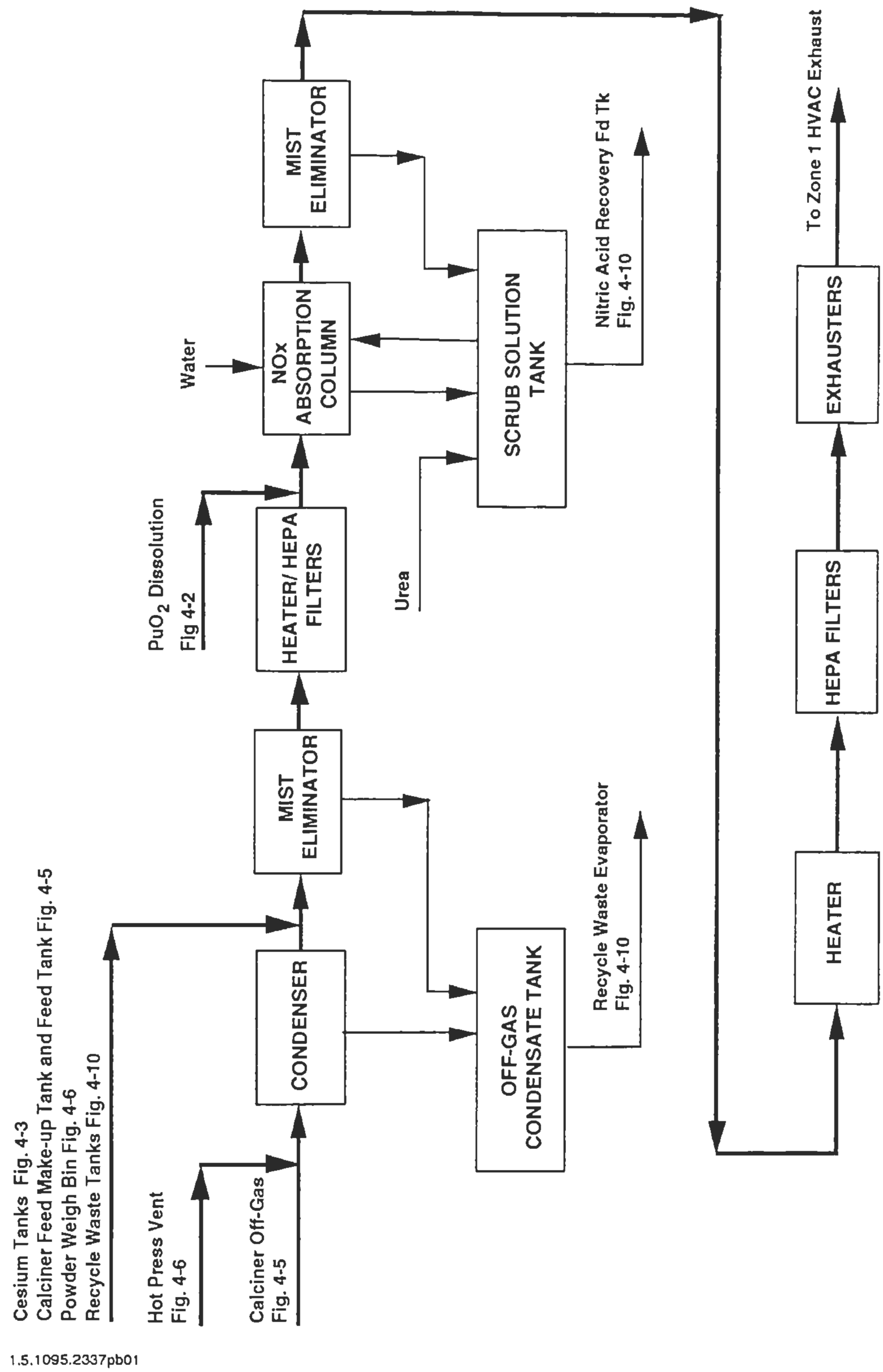


Figure 4-8. Off-gas treatment system process flow diagram.

4.8.2 Process Off-gas System Feeds

Feeds consist of off-gases collected from cesium tanks, calciner feed makeup and feed tanks, powder weigh bin, recycle waste tanks, hot press vent, calciner, MEO dissolver, and Pu storage tank.

4.8.3 Process Off-gas System Products

Products are scrubbed, filtered gases (sent to Zone 1 HVAC Exhaust).

4.8.4 Process Off-gas System Utilities Required

Electrical power is needed for heater, exhausters, pumps, instrumentation, and ventilation. Water is needed for process and cooling water.

4.8.5 Process Off-gas System Chemicals Required

The only chemical required is urea.

4.8.6 Process Off-gas System Special Requirements

DOE, NRC, and NEPA emission limits must be met.

4.8.7 Process Off-gas System Wastes Generated

Waste consists of condensate (sent to recycle waste evaporator) and scrub solution containing nitric acid (sent to nitric acid recovery).

4.9 Waste Management

4.9.1 Waste Management

Waste management processes for the CIF include waste handling and treatment operations for processing TRU waste, LLW, hazardous mixed waste, and industrial waste in aqueous, organic liquid, or solid form generated from the ceramic immobilization operations. The waste management operations will be in accordance with DOE Order 5820.2A and the Resource Conservation and Recovery Act (RCRA). It is assumed that TRU waste generated from CIF operations will be disposed of at the Waste Isolation Pilot Plant (WIPP) in accordance with WIPP Waste Acceptance Criteria. A waste management process flow diagram is shown in Fig. 4-9.

Radioactive wastes are processed in a Radwaste Management Building adjacent to the Process Building (See Sec. 2.1.3.2). The waste treatment processes include assay examination, sorting, separation, concentration, size reduction, organic destruction, and thermal treatment.

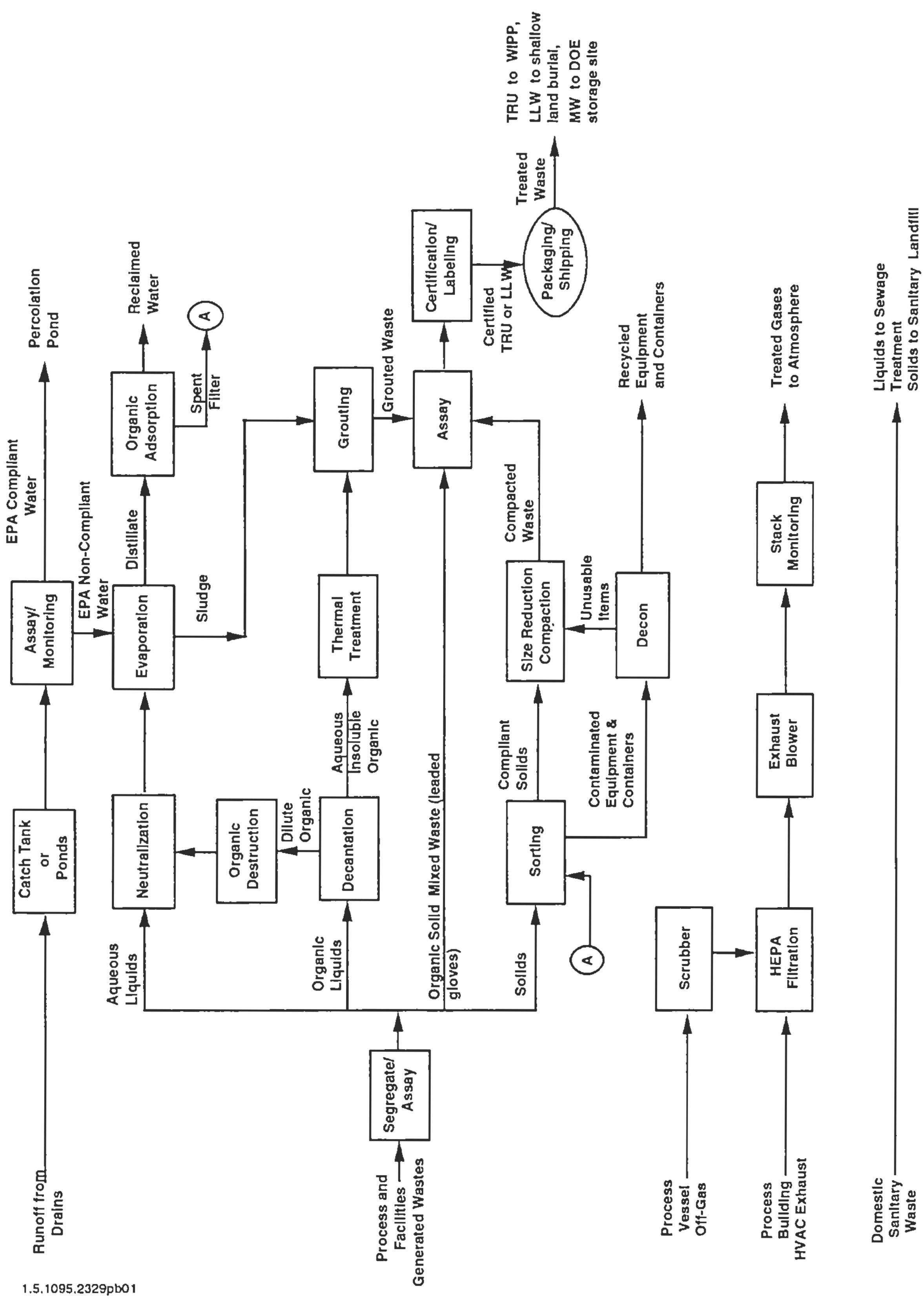


Figure 4-9. Waste management process flow diagram.

The wastes are converted to water that meets effluent standards or to grouted cement or compacted solid waste as final form products for disposal. Solid TRU wastes are packaged, assayed, and certified prior to shipping to the WIPP for permanent emplacement. Low-level solid wastes are surveyed and shipped to a shallow land buria site for disposal. A small quantity of solid mixed waste (mainly leaded glovebox gloves are packaged and shipped to a DOE waste treatment facility, pending future processing The waste treatment processes also includes equipment and waste container decontamination operations.

Radioactive off-gas condensate and decontamination effluents are collected in the recycle waste evaporator, as shown in Fig. 4-10. The contents are evaporated, and the bottoms are transferred to the calciner feed makeup tank for incorporation into the ceramic. The evaporator overhead is condensed and collected in a condensate tank. The condensate is sampled and analyzed to confirm that the radioactivity level is low.

The condensate is transferred outside the shielded cell to a nitric acid recovery feed tank, which is located in a contact maintenance area. After sampling, the scrub solution from NO_x absorption is also transferred to this feed tank. Nitric acid is recovered by distillation and is recycled for use in plutonium oxide dissolution. The condensate is transferred to the plant liquid waste treatment system.

Nonradioactive hazardous wastes will be treated, recycled, stored, and packaged fo offsite treatment or disposal as required by DOE Order 5480.1B and the applicable sections of 40 CFR 264, 265, 267, and 268.

4.9.2 Waste Management Feeds

Feed consists of runoff from potentially contaminated drains, process and facility wastes, process vessel off-gases, Process Building HVAC exhaust, and sanitary waste.

4.9.3 Waste Management Products

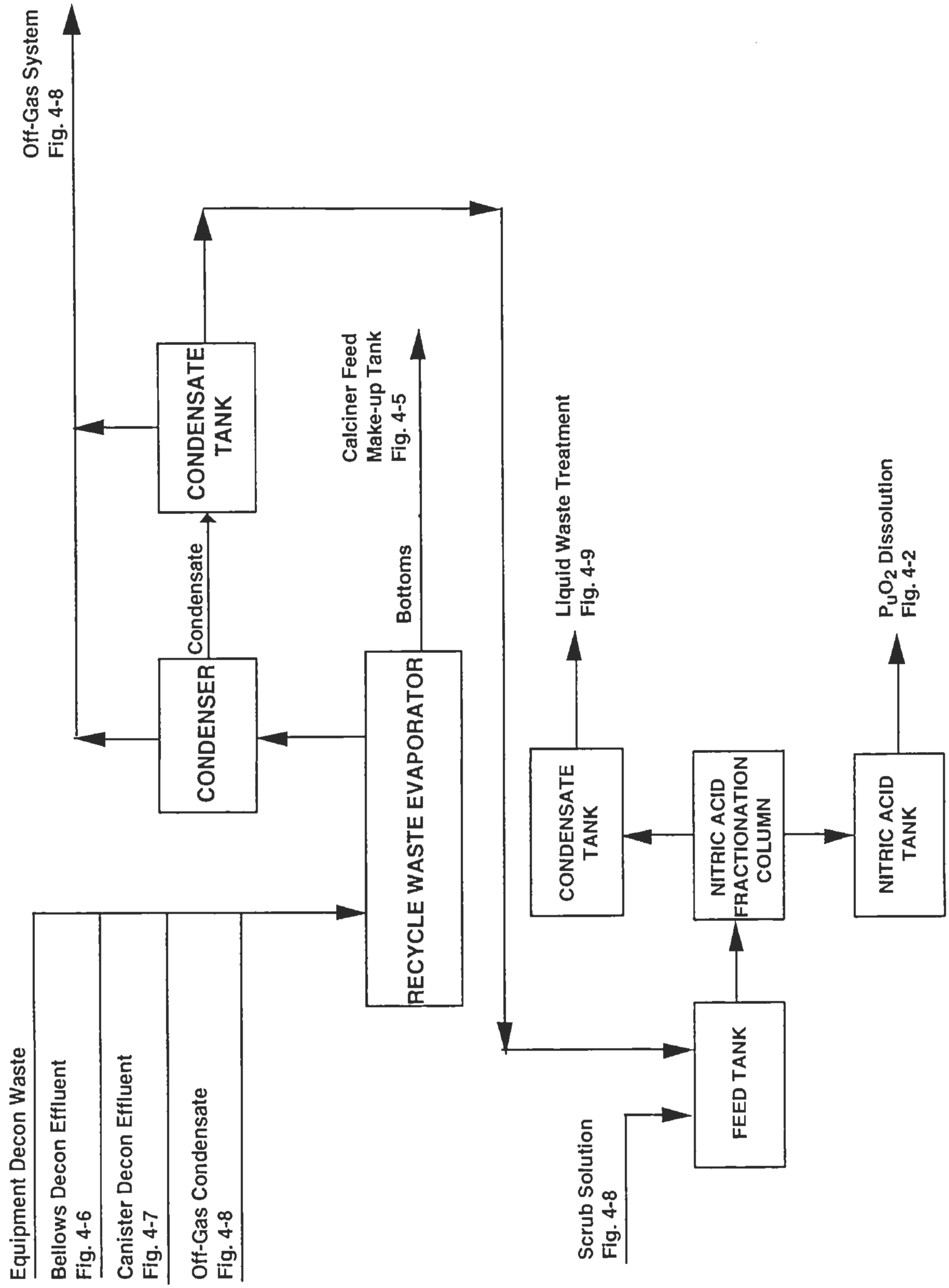
Products consist of treated water, certified TRU waste, LLW waste, mixed waste, treated gases, decontaminated equipment, other solid wastes, and reclaimed water for recycle to the process.

4.9.4 Waste Management Utilities Required

Required utilities are electrical power, cooling water, and compressed air.

4.9.5 Waste Management Chemicals Required

Chemicals required are caustics, acids, cement, organic adsorbent.



1.5.1095.2324pb03

Figure 4-10. Waste treatment process flow diagram.

4.9.6 Waste Management Special Requirements

Processing and storage must observe material and accountability controls, safeguards against diversion of plutonium, and other applicable DOE/NRC requirements for handling, treatment, storage, and shipment of LLW, TRU, mixed, and RCRA hazardous wastes.

4.9.7 Waste Management Wastes Generated

Wastes generated within the on-site waste management facilities includes liquid, solid, and off-gas LLW, TRU, mixed, and hazardous waste from waste processing, used and failed components and equipment, and contaminated rags, wipes, and clothing.

5.0 Resource Needs

This section describes the estimated resource impacts due to the construction of a new plutonium ceramic immobilization facility. Included are impacts during construction and operation of the CIF.

During the construction and operation of the CIF, various resources will be required. These resources will consist of utilities such as electricity, water, and fuels; chemicals such as cleaners, solvents, and lubricants; and other consumable materials and resources such as safety equipment, personal protective equipment, office spaces, and construction equipment.

The CIF will consist of the buildings and support facilities necessary to receive plutonium and other feed materials, maintain material control and accountability, process, incorporate into a ceramic matrix, and properly store the ceramic canisters until a permanent geological repository becomes available.

5.1 Materials/Resources Consumed During Operation

The CIF will require operations personnel for the process line, security forces to protect the SNM, maintenance personnel, administrative staff, engineers, health physic personnel, QA/quality control (QC) engineers, and laborers. The CIF will require personnel for transport of process feed materials, operating the process line, operation of cooling tower, maintenance shops, offices, cafeteria, and the remainder of the support facilities.

These new facilities will require chemicals (e.g., cleaning supplies, paints, concrete sealers), materials (e.g., administrative supplies, cleaning equipment), and resources (e.g., trucks, forklifts). The impacts are described in this section with expected consumption for a ceramic process line average throughput and an estimated peak throughput.

Operation of the CIF will require consumable materials and resources. Consumable materials will be items that will be used and eventually disposed. Resources will be functions, facilities, and equipment necessary to support the activities and are intended to be removed as serviceable at the completion of the project.

Consumable material use will generate sanitary waste and will include used safety equipment, cleaning equipment, plastic sheeting, and office waste. No hazardous waste is expected to be generated from consumable items. Operating equipment powered by an internal combustion engine (e.g., trucks, forklifts) will result in exhausts accounted for in current permits. Small amounts of hazardous waste will be generated by the anti-freeze and lubricating fluids removed from equipment during maintenance. Use of the other resources (e.g., administrative offices and support buildings) will not impact the environment.

5.1.1 Utilities Consumed

Annual utility consumption for facility operation is presented in Table 5-1 including electricity, fuel and water use. This is followed by Table 5-2 showing consumable chemical material annual use. An assumed average or normal throughput is the basis for the data.

Table 5-1. Utilities consumed during annual operation.

Utilities	Annual average consumption	Peak demand[1]
Electricity	25 GWh	3 MW
Liquid fuel	190,000 L (50,000 gal)	N/A[3]
Natural gas[2]	3.5×10^6 scm (124×10^6 scf)	N/A
Raw water	2.5×10^8 L (66×10^6 gal)	N/A

1 Peak demand is the maximum rate expected during any hour.
2 Standard Cubic Feet measured at 14.7 psia and 60°F.
3 Not applicable.

5.1.2 Water Balance

A preliminary conceptual water balance diagram for the Ceramic Immobilization Facility is shown in Fig. 5-1. This balance is based on the generic EPRI standard hypothetical east/west central site for nuclear power plants (As defined in Appendix F of the DOE Cost Estimate Guidelines for Advanced Nuclear Power Technologies, ORNL/TM-10071/R3). The only effect on the water balance for a greenfield site in a different location will be the stormwater runoff.

5.1.3 Chemicals Consumed

See Table 5-2.

Table 5-2. Annual chemicals consumed during operation.

Chemical	Quantity kg (lb)
Solid	
Silver nitrate	250 (540)
Ceramic precursors	32,000 (70,000)
Gadolinium	7,300 (16,000)
Titanium oxide	26,000 (57,200)
Titanium metal	830 (1,840)
Cement	730 (1,600)
Decontamination detergent	2,000 (4,400)
Resins	120 (260)
Nonionic polymers for cooling water	100 (220)
Phosphates for cooling waster	500 (1100)
Phosphonates for cooling water	100 (220)
Liquid	
Nitric acid	3,500 (7,800)
Sodium hydroxide	1,800 (4,000)
Potassium hydroxide	110 (240)
Urea	8,600 (19,000)
Gaseous	
Welding gas	200 cylinders

5.1.4 Radiological Materials Required

Annual requirements for radiological materials consist of the following:

- 5 tonne (11,000 lb) per year of plutonium—75% as plutonium oxide and 25% as plutonium metal.
- 64 kg (141 lb) per year of cesium in the form of CsCl salt packaged in welded stainless steel capsules.

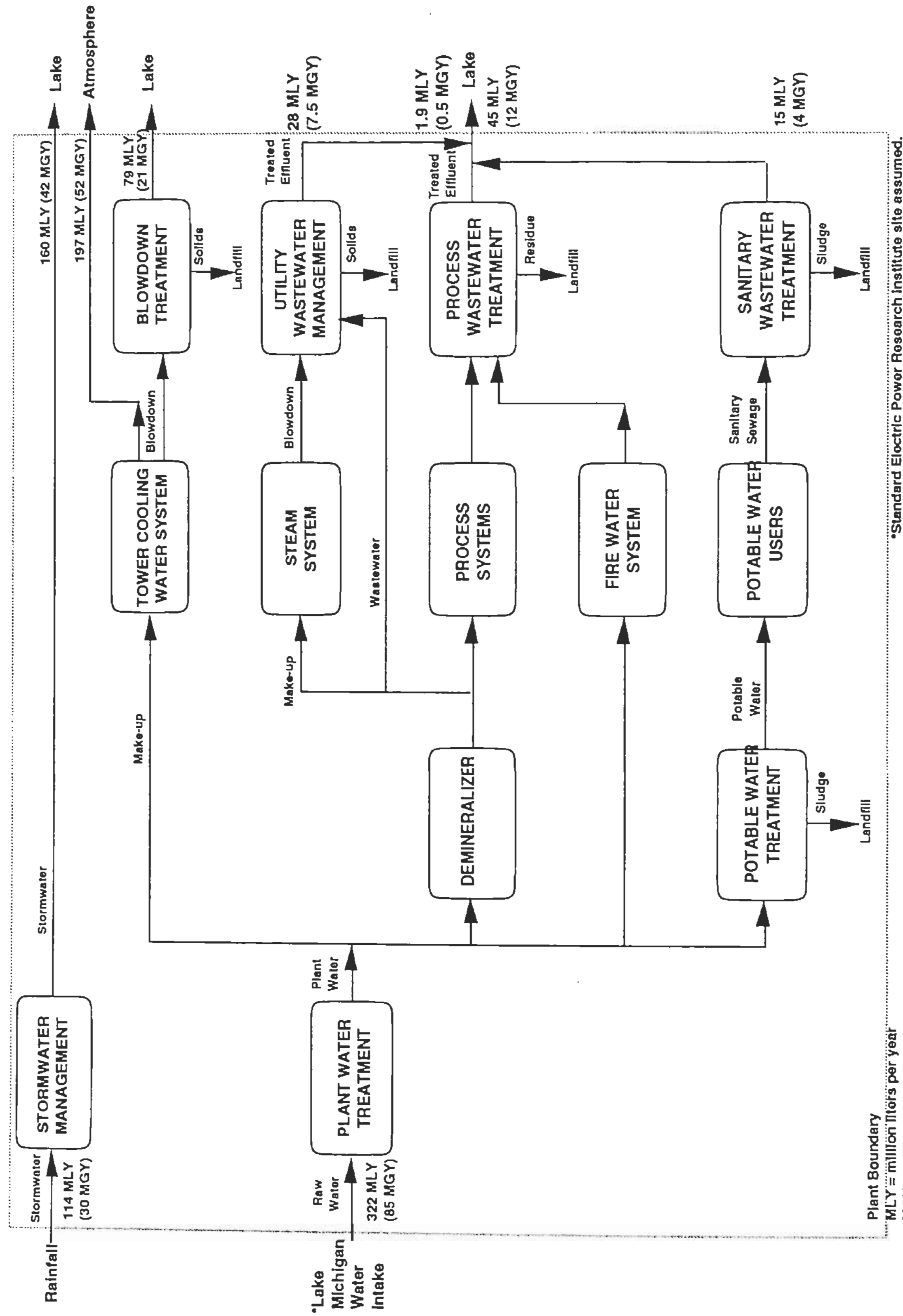


Figure 5-1. Water balance.

5.2 Materials/Resources Consumed during Construction

Table 5-3 provides an estimate of construction materials consumed during construction.

Table 5-3. Materials/resources consumed during construction.

Materials/resources	Total consumption	Peak demand[1]
Utilities		
Electricity	40,000 MWh	1.5 MW
Water	1.9×10^8L (5×10^7 gal)	30,000 L/day (8,000 gal/day)
Solids		
Concrete	27,000m^3 (35,000 yd^3)	
Steel	9,100 tonne (10,000 ton)	
Electrical raceway	25,000m (27,000 yd)	
Electrical wire and cable	60,000m (66,000 yd)	
Piping	30,000m (33,000 yd)	
Steel decking	15,000m^2 (18,000 yd^2)	
Steel siding	5,000 m^2 (6,000 yd^2)	N/A[3]
Built-up roof	3,500m^2 (4,200 yd^2)	
Interior partitions	1,100m^2 (1,200 yd^2)	
Lumber	5,500m^2 (7,200 yd^3)	
HVAC ductwork	100 tonne (110 ton)	
Asphalt paving	600 tonne (660 ton)	
Liquids		
Fuel	1.1×10^7L (3×10^6 gal)	N/A[3]
Gases		
Industrial gases (propane)[2]	76 scm (2,700 scf)	N/A[3]

1 Peak demand is the maximum rate expected during any hour.
2 Standard Cubic Feet Measured at 14.7 psia and 60°F.
3 Not applicable.

6.0 Employment Needs

6.1 Employment Needs During Operation

Table 6-1 provides an estimate of total employment during operations.

Table 6-1. Employment during operation.

Labor category	Number of employees
Officials and managers	40
Professionals	40
Technicians	90
Office and clerical	20
Craft workers (maintenance)	170
Operators/Line supervision	280
Safeguards and security	220
Total employees	860

6.2 Badged Employees at Risk of Radiological Exposure

Table 6-2 is a projected breakdown of dosimeter badged employees at the Ceramic Immobilization Facility who are expected to be routinely at risk of radiological exposure:

Table 6-2. Employees at risk of radiological exposure.

Labor category	Number at risk
Operators/Line supervision	190
Craft workers (maintenance)	120
Technicians	55
Professionals/managers	10
Safeguards and security	55
Total	430

In addition to the above, a small number of badged visitors may enter the radiological area, but this is envisioned to be on a nonroutine basis.

6.3 Employment Needs during Construction

Table 6-3 provides an estimate of total employment during construction.

Table 6-3. Number of construction employees needed by year.

Employees	Year 1	Year 2	Year 3	Year 4	Year 5
Total craft workers	270	540	900	720	450
Construction management and support staff	30	60	100	80	50
Total employment	300	600	1,000	800	500

7.0 Wastes and Emissions From the Facility

This section provides the annual emissions, effluents, waste generation and radiological emission estimates from the facility assuming peak operation. These are in the form of tables. Consistency with the facility and process descriptions are maintained. In general, the numbers are based on engineering judgment and preliminary calculations due to the preconceptual level of design.

7.1 Wastes and Emissions during Operation

7.1.1 Emissions

Table 7-1 summarizes the estimated emission rates of criteria pollutants, hazardous air pollutants, and other toxic compounds and gases during operations. Table 7-2 summarizes annual radiological emissions during operations.

7.1.2 Solid and Liquid Wastes

The type and quantity of solid and liquid wastes expected to be generated from operation of the Ceramic Immobilization Facility and the final waste products after treatment are shown in Table 7-3. The waste generations are based on factors from historic data on building size, utility requirements, and the projected facility workforce estimated in Table 6-1.

7.1.2.1 High-Level Wastes. There is no high-level radioactive waste generated from operation of the Ceramic Immobilization Facility.

7.1.2.2 Transuranic Wastes. Transuranic wastes will be generated from process and facility operations, equipment decontamination, failed equipment and used tools. Transuranic wastes are treated on-site in a waste handling facility to form grout or compact solid waste. Treated transuranic waste products are packaged, assayed, and certified prior to shipping to the WIPP for disposal.

7.1.2.3 Low-Level Wastes. Low-level wastes generated from operations of the facility are treated by sorting, separation, concentration, and size reduction processes. Final low-level waste products are surveyed and shipped to a shallow land burial site for disposal.

7.1.2.4 Mixed Transuranic Wastes. A small quantity of solid mixed waste, mainly rubber gloves and leaded glovebox gloves from the waste handling facility, will be generated during operations of the Ceramic Immobilization Facility. The mixed TRU waste is packaged to meet WIPP waste acceptance criteria (WIPPWAC) and stored on site until TRU can be shipped to WIPP.

Table 7-1. Annual emissions during operation.

Pollutants	Annual emissions kg (lb)
Criteria pollutants	
Sulfur dioxide	68 (150)
Nitrogen oxides (NOx)	6.6×10^5 (1.45×10^6)
Volatile organic compounds	81 (180)
Carbon monoxide	250,000 (550,000)
Particulate matter PM–10	770 (1,700)
Silver	$<10^{-6}$
Lead	0
Other pollutants	
Carbon dioxide	7.3×10^6 (16×10^6)
Hydrogen	1.4 (3)
Helium	Trace
Water vapor	150×10^6 (330×10^6)
Dissolved solids	24,000 (52,000)
Cooling tower chemicals	
Nonionic polymers	100 (220)
Phosphonates	1,000 (2,200)
Phosphates	500 (1,100)
Iron	10 (22)
Calcium	4,300 (9,400)
Magnesium	1,100 (2,400)
Sodium and potassium	330 (730)
Chloride	820 (1,800)
Fluoride	11 (24)

Table 7-2. Annual radiological emissions during operation.

Radiological isotope	Release rate GBq/yr (Ci/yr)
Cesium	$<3.7 \times 10^{-4}$ ($<1 \times 10^{-5}$)
Transuranics	$<3.7 \times 10^{-7}$ ($<1 \times 10^{-8}$)

Table 7-3. **Annual waste volumes during operation.**

Category	Generated quantities		Post treated	
	Solid m^3 (yd^3)	Liquid L (gals)	Solid m^3 (yd^3)	Liquid L (gal)
Radioactive and hazardous wastes				
Transuranic waste (TRU)	99 (130)	75,000 (20,000)	99 (130)	—
Low–level waste (LLW)	14 (18)	6,800 (1,800)	11 (14)	—
Mixed transuranic waste	0.7 (0.9)	0	0.7 (0.9)	—
Mixed low–level waste	0.15 (0.2)	0	0.15 (0.2)	—
Hazardous waste	19 (25)	38,000 (10,000)	19 (25)	38,000 (10,000
Nonhazardous (Sanitary) wastes				
Solid waste	920 (1,200)	—	920 (1,200)	—
Industrial waste water	—	1.9×10^7 (0.5×10^7)	—	1.9×10^7 (0.5×10^7)
Cooling water blowdown	—	5.2×10^7 (1.4×10^7)	—	5.2×10^7 (1.4×10^7)
Process waste water	—	1.1×10^7 (3×10^6)	—	1.1×10^7 (3×10^6)
Sanitary waste water	—	1.5×10^7 (0.4×10^7)	—	1.5×10^7 (0.4×10^7)
Storm water runoff[1]	—	1.1×10^8 (2.8×10^7)	—	1.1×10^8 (2.8×10^7)
Recyclable wastes	15 (20)	—	15 (20)	—

[1] Stormwater runoff based on generic EPRI site at Kenosha, Wisconsin per Appendix F of *DOE Cost Estimate Guidelines for Advanced Nuclear Power Technologies*, ORNL/TM-10071/R3.

7.1.2.5 Mixed Low-Level Wastes. Mixed wastes generated from the facility with radioactivity levels below the transuranic waste level (3700 Bq/g [100 nCi/g] will be classified as mixed low-level wastes and will be treated to the land disposal standards of RCRA.

7.1.2.6 Hazardous Wastes. Hazardous wastes will be generated from chemical makeup and reagents for support activities and lubricants and oils for process and support equipment. Hazardous wastes will be managed and hauled to a commercial waste facility off-site for treatment and disposal according to EPA RCRA guidelines.

7.1.2.7 Nonhazardous (Sanitary) Wastes. Nonhazardous sanitary liquid wastes generated in the facility are transferred to an on-site sanitary waste system for treatment. Nonhazardous solid wastes, such as domestic trash and office waste, are hauled to an offsite municipal sanitary landfill for disposal.

7.1.2.8 **Nonhazardous (Other) Wastes.** Other nonhazardous liquid wastes generated from facilities support operations (e.g., cooling tower and evaporator condensate) are collected in a catch tank and sampled before being reclaimed for other recycle use or release to the environment.

7.2 Wastes and Emissions during Construction

7.2.1 Emissions

Estimated emissions from construction activities of the Ceramic Immobilization Facility during the peak construction year are shown in Table 7-4. The emissions are based on the construction land disturbance and vehicle traffic (for dust particulate pollutant) and the fuel and gas consumption (for chemical pollutants) estimated in Table 5-3. The peak construction year is based on a construction schedule as the labor force distribution shown in Table 6-2.

7.2.2 Solid and Liquid Wastes

Estimated total quantity of solid and liquid wastes generated from activities associated with construction of the facility is shown in Table 7-5. The waste generation quantities are based on factors from historic data on construction area size and construction labor force estimated in Table 6-3.

Table 7-4. Emissions during the peak construction year.

Criteria pollutants	Quantity tonne (ton)
Sulfur dioxide	6.4 (7)
Nitrogen oxides (NOx)	100 (110)
Volatile organic compounds	7.3 (8)
Carbon monoxide	730 (800)
Particulate matter PM-10	820 (900)
Lead	N/A

7.2.2.1 **Radioactive Wastes.** There are no radioactive wastes generated during construction of the Ceramic Immobilization Facility since the site is assumed to be a greenfield site.

7.2.2.2 **Hazardous Wastes.** Hazardous wastes generated from construction activities, such as motor oil, lubricants, etc. for construction vehicles will be managed and hauled to commercial waste facility offsite for treatment and disposal according to EPA RCRA guidelines.

Table 7-5. **Total wastes generated during construction.**

Waste category	Quantity
Hazardous solids	100 yd^3
Hazardous liquids	64,000L (17,000 gal)
Nonhazardous solids (construction debris)	810 tonne (900 ton)
Nonhazardous liquids	
Concrete batch plant[1]	1.5×10^7L (4×10^6 gal)
Service water[2]	1.9×10^7L (5×10^6 gal)
Sanitary waste[3]	1.1×10^8L (30×10^6 gal)
Construction Storm Water[4]	7.5×10^8L (2×10^8 gal)

1 Based on yards of concrete produced
2 Based on estimated construction needs
3 Based on average construction workforce size and 5-year construction duration
4 Construction storm water runoff based on total land area disturbed and generic EPRI site at Kenosha, Wisconsin.

7.2.2.3 Nonhazardous Wastes. Solid nonhazardous wastes generated from construction activities, e.g., construction debris and rock cuttings, are to be disposed of in a sanitary landfill. Liquid nonhazardous wastes are either treated with a portable sanitary treatment system or hauled to off-site facilities for treatment and disposal.

8.0 Design Process for Accident Mitigation

8.1 Operational and Design Basis, and Beyond Design Basis Bounding Accidents

The CIF is a Hazard Category 2 facility as defined in DOE-STD-1027-92. As such, it will require a detailed safety analysis report and risk assessment under DOE Order 5480.23. This section presents a preliminary set of accidents postulated for the CIF. The description of each accident includes the following elements:

- A description of the accident scenario,
- An estimate of the frequency of the scenario based on engineering judgment because the design of the CIF is not advanced enough to justify use of rigorous risk analysis techniques,
- An estimate of the amount of radioactive at risk in the accident based on the block flow diagrams and the equipment lists,
- An estimate of the fraction of material at risk that becomes airborne in respirable form, and
- An estimate of the fraction of material airborne in respirable form that is removed by filtration of the ventilation system effluents.

Based on these postulated accidents and on DOE and USNRC guidance, the following systems, structures, and components (SSCs) in the CIF are assumed to be safety class items:

- Structures housing plutonium and/or cesium (per DOE Order 6430.1A 1300-3.2 since collapsing or breaching these structures could result in an unconfined release of radioactivity with unacceptable consequences)
- Ventilation system(s) required to maintain confinement following an accident (per DOE 6430.1A 1300-3.2 since loss of confinement during an earthquake could result in an unmitigated release of radioactive material and per DOE 6430.1A 1300-7.2, which requires that at least one confinement system be designed to withstand the effects of severe natural phenomena and man made events)
- Pu storage vault racks and canister storage vault racks (per DOE Order 6430.1A since collapse of these storage racks could produce a nuclear criticality accident)
- Other items required for criticality safety including monitoring equipment required to assure that Pu and neutron absorber concentrations are within limits and the criticality alarm system (per DOE Order 6430.1A 1300-3.2)
- Effluent monitoring equipment required to assess releases of radioactivity to the environment during and following a DBA (per DOE Order 6430.1A 1300-3.2)
- Emergency power and UPS systems (as required for the SSCs to perform their safety functions per DOE 6430.1A 1330-3.2)
- Gloveboxes containing Pu in powder form (Seismic Category I per USNRC Regulatory Guide 3.14)

- Pu storage and process containers, including tankage and piping, that are not contained in DBE resistant gloveboxes (Seismic Category I per USNRC Regulatory Guide 3.14)

The accidents postulated for nuclear facilities can be divided into three categories depending on the accident initiator: natural phenomena events, external events, and internal events. The following sections describe accidents in each of theses categories considered for this assessment. Table 8-1 summarizes the accident scenarios and releases.

8.1.1 Operational and Design Basis Accidents

8.1.1.1 Natural Phenomena. The following natural phenomena are considered applicable to the CIF and are treated as design basis events:

- Earthquake
- Tornado
- Flooding.

Other natural phenomena such as volcanic activity or tidal waves are not considered likely to be credible for the CIF site. Such events would be addressed in the future if warranted by the site selected for the facility.

Earthquake. The design basis earthquake (DBE) for the CIF will be chosen in accordance with UCRL-15910 (DOE-STD-1020-92). Safety class systems, structures, and components (SSCs) are designed to withstand the DBE. Earthquakes exceeding the magnitude of the DBE are extremely unlikely accidents as defined in DOE-STD-3005-YR. Earthquakes of sufficient magnitude to cause the failure of safety class SSCs are considered incredible events as defined in DOE-STD-3005-YR.

Given the safety class items assumed for the CIF, an earthquake would not directly cause a release of radioactive material nor would it cause a criticality accident. It is postulated, however, that the earthquake starts a fire in the room housing the Pu metal glovebox line. The fire is unimpeded and breaches a glovebox containing Pu metal. The inert atmosphere is lost and the fire ignites the Pu. The ventilation removes plutonium containing gases from the area. The gases pass through a filtration system and are then released to the environment. It is assumed that 0.1% of the Pu at risk becomes airborne in respirable form. This glovebox line processes approximately 7 kg (15.4 lb) of plutonium per day. Therefore, at most 7 kg (15.4 lb) of Pu are at risk as a result of the earthquake.

This material is released to ventilation Zone 2. Assuming a two-stage HEPA filter system, the fraction of particles released penetrating the filter would be 10^{-6}. Therefore, 10^{-7}% of the Pu at risk would reach the environment as respirable particles.

Tornado. The design basis tornado (DBT) for the CIF will be chosen in accordance with UCRL-15910 (DOE-STD-1020-92). Safety class systems, structures, and components are designed to withstand the DBT and DBT-generated tornado missiles. Tornadoes exceeding the magnitude of the DBT are extremely unlikely accidents as defined in DOE-STD-3005-YR. Tornadoes of sufficient energy to cause the failure of safety class SSCs are considered incredible events as defined in DOE-STD-3005-YR.

Safety related SSCs for the CIF are enumerated in section 8.1 above. Given these SSCs, it is reasonable to assume that it is not credible for a tornado to cause a release of radioactive material or an accidental criticality event at the CIF.

Floods. Flooding is of particular concern at plutonium processing facilities such as the CIF because of the potential for nuclear criticality accidents. The CIF will be designed to preclude flooding of areas that contain Pu. The design basis flood (DBF) for the CIF will be chosen in accordance with UCRL-15910 (DOE-STD-1020-92). Safety class systems, structures, and components are designed to withstand the DBF. Floods exceeding the magnitude of the DBF are extremely unlikely accidents as defined in DOE-STD-3005-YR. Floods of sufficient magnitude to cause the failure of safety class SSCs are considered incredible events as defined in DOE-STD-3005-YR.

Safety related SSCs for the CIF are enumerated in Section 8.1 above. Given these SSCs, it is reasonable to assume that it is not credible for a flood to cause a release of radioactive material or an accidental criticality event at the CIF.

8.1.1.2 External Events. These are events originating offsite. They are site specific and are not considered at this stage of conceptual design. External events that will be addressed in the future include the following:

- Aircraft hazards
- Hazards from nearby facilities (explosions, missiles, chemicals)
- Transportation hazards (explosives, chemicals).

8.1.1.3 Internal Events—Glovebox Fire. An unimpeded fire begins in the room housing the glovebox line. The fire breaches a glovebox containing Pu metal. The inert atmosphere is lost and the fire ignites the Pu. The ventilation removes plutonium containing gases from the area. The gases pass through a filtration system and are then released to the environment. This glovebox line processes approximately 7 kg (15.4 lb) of plutonium per day. Therefore, at most 7 kg (15.4 lb) of Pu are at risk in this scenario. It is assumed that 0.1% of the Pu at risk becomes airborne in respirable form.

This material is released to ventilation Zone 2. Assuming a two stage HEPA filter system, the fraction of particles released penetrating the filter would be 10^{-6}. Therefore, 10^{-7}% of the Pu at risk would reach the environment as respirable particles.

This is judged to be an unlikely accident as defined in DOE-STD-3005-YR.

Cesium Fire. The combustible loading for the processes involving ^{137}Cs is very low. The cesium is in the form of cesium chloride which is not flammable. Therefore, this event is judged to be an incredible accident as defined in DOE-STD-3005-YR (i.e., its frequency is less than 10^{-6} per year).

Fire in the Remote Process Cell. The combustible loading in the remote process cells is very low. The processes involve no flammable materials. Small electrical fires are possible. Such fires would be localized and extinguished by the fire protection system. In any event, the combustible loading is low enough that it is unlikely that radioactive material could be released as a result of this fire. Therefore, release of radioactivity as a result of a fire in the remote process cells is judged to be an incredible accident as defined in DOE-STD-3005-YR (i.e., its frequency is less than 10^{-6} per year).

Uncontrolled Chemical Reactions. There is no significant potential in the CIF processes for uncontrolled chemical reactions that could lead to releases of radioactive material. Radiolytic hydrogen will be produced in the solutions in the CIF. Accumulation of hydrogen within the tanks would require that the tanks be isolated from the off-gas treatment system for a considerable period of time. At this point, it is believed that hydrogen accumulation in CIF process vessels is unlikely to be a concern. However, this is an area that will be further evaluated.

Glovebox Criticality. The criticality safety of the glovebox operations at CIF depend on controlling the inventory and configuration of fissile material in the glovebox. The mass limits will be chosen to preclude criticality in the event of double batching and automated accountability systems will be employed. However, these criticality controls depend on procedures to some extent. In this scenario controls are violated so that additional fissile material is introduced into a double batched glovebox. This results in an accidental criticality.

This event is modeled based on USNRC Regulatory Guide 3.35. The critical assembly is disrupted by the initial energy release and the event is terminated. There are 10^{18} fissions in the initial pulse. One-hundred percent of the noble gases, 25% of the halogens, and 0.1% of the ruthenium become airborne. This activity is released to the Zone 1 ventilation system. The exhaust HEPA filters do not mitigate the release of noble gases and halogens. Assuming a three-stage system, the exhaust filtration system does remove all but 10^{-6}% of the particulates.

This is judged to be an extremely unlikely accident as defined in DOE-STD-3005-YR.

MEO Dissolver and Plutonyl Nitrate Storage Tank Criticality. These are geometrically favorable vessels. While the diameter of these tanks is larger than the single parameter limit for metal Pu systems, the combination of favorable geometry and process controls is such that this is judged to be an incredible accident as defined in DOE-STD-3005-YR.

Calciner Feed Mixing Tank Criticality. The criticality safety of this tank depends on controlling the concentrations of the gadolinium and plutonyl nitrate solutions in the tank. Controls could fail so that the limits on fissile material and absorber concentration are violated. A pulsed criticality event occurs as a result.

This event is modeled based on USNRC Regulatory Guide 3.35. There are 10^{18} fissions in the initial pulse; 47 pulses of 1.9×10^{17} fissions each occur at 10-min intervals for a total of 10^{19} fissions over 8 hr. One hundred liters evaporate during the incident.

One hundred percent of the noble gases, 25% of the halogens, 0.1% of the ruthenium, and 0.05% of the salts associated with the evaporated water become airborne. This activity is released to the Zone 1 ventilation system. The exhaust HEPA filters do not mitigate the release of noble gases and halogens. Assuming a three-stage system, the exhaust filtration system does remove all but 10^{-6}% of the particulates.

This is judged to be an extremely unlikely accident as defined in DOE-STD-3005-YR.

Plutonyl Nitrate Storage Criticality. As described in Sec. 2.2.4, the design of the storage array precludes criticality even if the indexed stacker retriever should malfunction and there is multiple double batching. The facility is designed to preclude flooding of this area. Therefore, a nuclear criticality accident in the Pu storage vault is judged to be an incredible accident as defined in DOE-STD-3005-YR.

Canister Storage Criticality. The array in the canister storage area is critically safe. The racks are designed to maintain the geometry of the array under all postulated accidents and natural phenomena conditions. The design of the storage facility precludes multiple batching. The facility is designed to preclude flooding of this area. Therefore, a nuclear criticality accident in the canister storage vault is judged to be an incredible accident as defined in DOE-STD-3005-YR.

Bellows Drop. A bellows is dropped 6 m (19.7 ft) during handling. The force of the drop fractures the ceramic material and ruptures the bellows. Respirable fines of ceramic are released to the cell and collected by the ventilation system. The airborne fines pass through the ventilation system filters and are released to the environment. At risk in this accident are 4 kg (8.8 lb) of plutonium and 50 g (2 oz) or 150 TBq (4330 Ci) of ^{137}Cs .

Of the ceramic that becomes airborne, 0.01% is respirable fines. This release is to the Zone 1 ventilation zone. Assuming a three-stage HEPA filter system, 10^{-6}% of the airborne material will penetrate the filtration system. Therefore, 10^{-10}% of the material at risk will reach the environment.

This is judged to be an unlikely accident as defined in DOE-STD-3005-YR.

Canister Drop. A canister is dropped 6 m (19.7 ft) during handling. The force of the drop fractures the ceramic material but does not rupture the canister. The ceramic fines are contained within the canister 80 kg (176 lb) of plutonium and 1 kg (2.2 lb) or

3200 TBc
radioact

This

Cesi
force of

Calciner Product Bin Spill. A product overflows spilling 44 kg (96.8 lb) of powder (10% of the vessel contents) onto the floor from a height of 3 m (9.8 ft). The spill spread out in a safe geometry. The spill is cleaned up within 2 hr. Some of the spill becomes airborne as respirable particles. There is little or no entrainment from the spill because of the quick response time. The spill contains 5 kg (11 lb) of Pu and 64 g (2.3 oz) or 101 TBq (2740 Ci) of ^{137}Cs.

No more than 0.07% of the spill becomes airborne as respirable aerosol. This material is released to ventilation Zone 1. Assuming a three-stage HEPA system, 10^{-6}% of the airborne material is released to the environment. Therefore, no more than 7×10^{-10}% of the material at risk reaches the environment.

Loss of Off-Site Power. CIF incorporates emergency and uninterruptible power sources as required to cope with a complete loss of off-site power. Therefore, a loss of off-site power will not directly result in a release of radioactivity.

This is judged to be an anticipated accident as defined in DOE-STD-3005-YR.

8.1.2 Beyond Design Basis Accidents

8.1.2.1 Natural Phenomena. Beyond design basis natural phenomena are not considered.

8.1.2.2 External Events. These are events originating offsite. They are site specific and are not considered at this stage of preconceptual design. Beyond design basis external events will be addressed in the future.

8.1.2.3 Internal Events—Cesium Fire. The combustible loading for the processes involving ^{137}Cs is very low. The cesium is in the form of cesium chloride which is not flammable. Therefore, this event is judged to be an incredible accident as defined in DOE-STD-3005-YR (i.e., its frequency is less than 10^{-6} per year).

Assuming, however, that it were possible expose the cesium chloride to a large fire, it would be conservative to assume that the fraction airborne is the same as the fraction of Pu (a pyrophoric material) made airborne by fire. This fraction is 0.001. Any cesium affected by the fire would be released to the Zone 1 ventilation system. Assuming a three-stage HEPA filter system, the fraction of the released activity penetrating the filter system would be 10^{-6}%. Therefore, the fraction of the cesium at risk that could potentially reach the environment as a result of fire would be less than 10^{-9}%.

The cesium storage area contains approximately 50 capsules of cesium chloride. The average activity per capsule in 1994 was about 1500 TBq (40,000 Ci) of ^{137}Cs per capsule. Assuming that operations at the CIF begin in 2013, the total activity in the storage area would be 4.8×10^4 TBq (1.3×10^6 Ci) of ^{137}Cs. This is the maximum quantity of cesium at risk.

Fire in the Remote Process Cell. The combustible loading in the remote process cells is very low. The processes involve no flammable materials. Small electrical fires are possible. Such fires would be localized and extinguished by the fire protection system. In any event, the combustible loading is low enough that it is unlikely that radioactive material could be released as a result of this fire. Therefore, release of radioactivity as a result of a fire in the remote process cells is judged to be an incredible accident as defined in DOE-STD-3005-YR (i.e., its frequency is less than 10^{-6} per year).

Assuming that a large fire were possible in the process cell, the plutonium and cesium in the process equipment would potentially be at risk. It is assumed that the fire ruptures the calciner product bins and that the contents are exposed to the fire. By analogy with the glovebox fire described in Sec. 8.1.1.3, it is assumed that the fraction made airborne by the fire is 0.001. This material would be released to the Zone 1 ventilation system. Assuming a three-stage HEPA filter system, the fraction of the released activity penetrating the filter system would be 10^{-6}%. Therefore, the material at risk that could potentially reach the environment as a result of fire would be less than 10^{-9}%.

The calciner product bins contain approximately 50 kg (110 lb) of Pu and 2000 TBq (55,000 Ci) of cesium. This would be the maximum quantity of radioactivity at risk in the fire.

Uncontrolled Chemical Reactions. There is no significant potential in the CIF processes for uncontrolled chemical reactions that could lead to releases of radioactive material. Radiolytic hydrogen will be produced in the solutions in the CIF. Accumulation of hydrogen within the tanks would require that the tanks be isolated from the off-gas treatment system for a considerable period of time. At this point, it is believed that hydrogen accumulation in CIF process vessels is unlikely to be a concern. However, this is an area that will be further evaluated.

Assuming, however, that hydrogen detonations in the CIF process vessels were possible, the bounding case would involve the calciner feed tank. It would be conservative to assume that 10% of the tank inventory becomes airborne. This material would be released to the Zone 1 ventilation system. Assuming a three-stage HEPA filter system, the fraction of the released activity penetrating the filter system would be 10^{-6}%. Therefore, the material at risk that could potentially reach the environment as a result of an uncontrolled chemical reaction would be less than 10^{-9}%.

This tank contains approximately 25 kg (55 lb) of Pu and 1000 TBq (27,400 Ci) of cesium.

Criticality Accidents. The models of the criticality events at the CIF are based on guidance in Reg. Guide 3.35. Based on this guidance, the events involve 10^{18} fissions in the initial pulse. For criticality events involving solutions, there are 47 additional pulses over an 8-hr period involving 10^{17} fissions per pulse.

Criticality events with larger number fissions are judged to be incredible events (as defined in DOE-STD-3005-YR) for the CIF. However, the discussion in Reg. Guide 3.35 indicates that such events are theoretically possible. The largest criticality mentioned in the Reg. Guide involves a total of 3×10^{20} fissions. Assuming this were possible at the CIF, there would be 5×10^{19} fissions in the initial pulse and 47 additional pulses over 8 hr each involving 5×10^{18} fissions.

Per Regulatory Guide 3.35, 100% of the noble gases, 25% of the halogens, and 0.1% of the ruthenium and salts would become airborne. This activity would be released to the Zone 1 ventilation system. The exhaust HEPA filters do not mitigate the release of noble gases and halogens. Assuming a three stage system, the exhaust filtration system does remove all but 10^{-6}% of the particulates.

8.2 Facility–Specific Potential Mitigating Features

See section 2.2.

9.0 Transportation

9.1 Intrasite Transportation

Intrasite transport of radiological materials will be limited to the transp shipping containers of plutonium metal and oxide, and cesium capsules. A handling or use of radiological materials will be confined to the Plutonium Building, the Hot Maintenance Shop and the Radwaste Management Buildi

Cesium capsules are received on site at the Plutonium Processing Buildi approved truck or rail transport. Plutonium metal or oxide will be received facility via a Safe Secure Trailer (SST).

Any radiological material shipped offsite will be in the form of waste w packaged and shipped from either the Canister Storage Building or the Rad Management Building in accordance with DOT requirements.

Hazardous chemicals will be received from offsite and stored in the buil they are used so that there will be no intrasite transport required. Hazardou will be used in the Plutonium Processing Building, the Radwaste Managem Building, the Hot Maintenance Shop, the Support Utilities Building, the Coc the Industrial Waste Treatment Facility and the Sanitary Waste Treatment P

9.2 Intersite Transportation

Intersite transportation data for off-site shipment of radioactive feed and materials is shown in Table 9-1.

Plutonium feed to the plant is assumed to arrive in either metal or oxide plutonium is assumed to arrive in standard DOT/DOE/NRC approved 6M, shipping packages with a maximum of 4.5 kg (9.9 lb) of plutonium per pack number of packages per shipment is 40, although the number of packages m depending on the amount of plutonium in a package. Since the plant throug tonne (5.5 ton) Pu per year, the average number of plutonium shipments per and the total number of plutonium shipments over the life of the project is 2

Table 9-1. Intersite transportation data.

	Input material #1	Input material #2	Output material #1
Transported materials			
Type	Plutonium	Cesium	Pu/Cs/Gd meramic
Physical form	Metal or oxide	Salt	Ceramic
Chemical composition	Pu or PuO_2	CsCl	See Sec. 2.1.1
Packaging			
Type	6 M/2R-like	Hanford capsules in BUSSR-1 C of C #9511	36 cm (14 in.) diameter × 244 cm (8 ft) modified DHLW canisters in SRS HLW rail cask
Certified by	DOT/DOE/NRC e.g., Package Certificate of Compliance Number (C of C#) 9966 (SR Chalfant)	DOE/NRC BUSSR-1 C of C #9511	Not currently certified
Identifier	6M/2R-like	BUSSR-1	DHLW rail cask (modified DHLW canister with SRS HLW rail cask)
Package weight	86 to 286 kg (190 to 630 lb)	14.7 tonne (17 ton)	86 tonne (96 ton)
Material weight	max of 4.5 kg (9.9 lb) Pu	4.7 kg (10 lb) w/i the BUSSR-1	656 kg (1440 lb) Pu/Cs/Gd ceramic
Isotopic content (%)	93% ^{239}Pu, 6% ^{240}Pu, 1% trace isotopes	56% ^{133}Cs 19% ^{135}Cs 25% ^{137}Cs	12% Pu; 1000 g Cs; 52 kg Gd; remainder, ceramic
Average shipping volume			
Quantity/year	5 tonne (5.5 ton) Pu	64 kg (140 lb) Cs	5 tonne (5.5 ton) Pu
Average number of packages[1] shipped/yr	1,100	136 Cs capsules	64 DHLW canisters
Estimated number of packages[1] shipped over life of the project	11,000	1,360 Cs capsules	640 DHLW canisters
Number of packages[1] per shipment	40	10	1 to 5 DHLW canisters in SRS HLW rail cask
Number of shipments/yr	28	14	13 to 64
Number of shipments over the life of the project	280	140	128 to 640
Routing			
Mode of transport:	SST	Commercial truck or rail	Commercial truck or rail
Destination facility type	SNM vault	Shielded vault	Repository

[1] Packages are individual quantities of material, not the shipping containers in which multiple packages will be shipped.

Cesium feed to the facility is assumed to arrive in Hanford-designed CsCl capsul shipped in BUSSR-1 Certificate of Compliance Number (C of C#) 9511 shipping cask with a capacity of 10 CsCl capsules per cask. Assuming one cask per shipment, the t number of shipments per year of CsCl is expected to be about 14 and the total numb of CsCl shipments over the life of the project is about 140.

Immobilized plutonium ceramic product is contained in 35.6-cm (14-in.) -diam × 244-cm (8-ft)-high product canisters. The shipping mode of these containers is not determined at this time. Early monitored retrievable storage studies (in 1985) defined the cask configuration shown in Table 9-1 for transporting defense high-level waste from the Savannah River DWPF. The bounding condition of one canister per shipme results in an average of 64 shipments per year or 640 shipments over the life of the project.

Preliminary Evaluation of Alternative Waste Form Solidification Processes, April, 1980, PNL-3244/UC-70, prepared by Battelle Pacific Northwest Laboratories for US DOE.

Special Isotope Separation Production Plant Preliminary Design Report, April 30, 1987, Bechtel National, Inc., Westinghouse Idaho Nuclear, Co., and Lawrence Livermore National Laboratory.

Special Isotope Separation Facility Design, September 30, 1990, prepared by Bechtel National, Inc. for the US DOE Idaho Operations Office, Idaho Falls, ID.

Special Isotope Separation Facility Final Environmental Impact Statement,, November, 1988, DOE/EIS-0136, US DOE Idaho Operations Office, Idaho Falls, ID.

Final Environmental Impact Statement, Defense Waste Processing Facility Savannah River Plant, 1982, DOE/EIS-0082, Savannah River Site, Aiken, South Carolina.

Final Environmental Impact Statement and Environmental Impact Report for Continued Operation of Lawrence Livermore National Laboratory and Sandia National Laboratories, Livermore, August, 1992, DOE/EIS-0157/SCH90030847 USDOE and University of California.

11.0 Glossary

List of Acronyms

Ag	silver
AGNS	Allied-General Nuclear Services
ANS	American Nuclear Society
ANSI	American National Standards Institute
ANSTO	Australian Nuclear Science Technology Organisation
BNFO	Bechtel Nuclear Fuel Operations
BNL	Brookhaven National Laboratory
CAS	central alarm system
CCTV	closed-circuit television
cfm	cubic feet per minute
CFR	Code of Federal Regulations
CIF	Ceramic Immobilization Facility
Cs	cesium
D&D	decontamination and decommissioning
DBA	Design Basis Accident
DBE	Design Basis Earthquake
DBF	Design Basis Flood
DBT	Design Basis Tornado
DOE	Department of Energy
DOT	Department of Transportation
DWPF	Defense Waste Processing Facility
EIS	environmental impact statement
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
ES&H	environment, safety, and health
FMD PEIS	fissile materials disposition programmatic environmental impact statement
FTE	full-time equivalent
gpd	gallons per day
gpm	gallons per minute

GWh	gigawatt hours
HEPA	high-efficiency particulate air
HEU	highly-enriched uranium
HLW	high-level waste
HVAC	heating, ventilation, and air conditioning
IAEA	International Atomic Energy Agency
IEEE	Institute of Electrical and Electronics Engineers
INEL	Idaho National Engineering Laboratory
kV	kilovolt
k_{eff}	effective neutron multiplication factor
KD	Key decision
LLNL	Lawrence Livermore National Laboratory
LLW	low-level waste
Lpd	liters per day
Lpm	liters per minute
M	molar
MAA	material access area
MC&A	material control and accountability
MEO	mediated electromechanical oxidation
MPa	megapascals
MW	megawatt
NAS	National Academy of Sciences
NFPA	National Fire Protection Association
NMC&A	nuclear material control and accountability
NO_x	nitrous oxides
NRC	Nuclear Regulatory Commission
ORNL	Oak Ridge National Laboratory
ORR	Operational Readiness Review
PEIS	programmatic environmental impact statement
PIDAS	Perimeter Intrusion Detection and Assessment System
PNL	Pacific Northwest Laboratory
PAP	Personal Assurance Program
PSAP	Personal Security Assurance Program
psi	pounds per square inch
psig	pounds per square inch gauge
RCRA	Resource Conservation and Recovery Act

ROD	record of decision
SAR	Safety Analysis Report
SAS	secondary alarm station
scf	standard cubic feet
SFM	surplus fissile material
SIS	special isotope separation
SNM	special nuclear material
SPO	security police officer
SSC	safety class systems, structures, and components
SST	safe secure trailer
TBD	to be determined
TID	tamper indicating device
TPSS	two-person surveillance system
TRU	transuranic
UBC	Uniform Building Code
UCNI	Unclassified Controlled Nuclear Information
UCRL	University of California Radiation Laboratory
UPS	uninterruptible power supply
USNRC	United States Nuclear Regulatory Commission
VA	vulnerability assessment
WIPP	Waste Isolation Pilot Plant
WIPPWAC	Waste Isolation Pilot Plant Waste Acceptance Criteria

GWh	gigawatt hours
HEPA	high-efficiency particulate air
HEU	highly-enriched uranium
HLW	high-level waste
HVAC	heating, ventilation, and air conditioning
IAEA	International Atomic Energy Agency
IEEE	Institute of Electrical and Electronics Engineers
INEL	Idaho National Engineering Laboratory
kV	kilovolt
k_{eff}	effective neutron multiplication factor
KD	Key decision
LLNL	Lawrence Livermore National Laboratory
LLW	low-level waste
Lpd	liters per day
Lpm	liters per minute
M	molar
MAA	material access area
MC&A	material control and accountability
MEO	mediated electromechanical oxidation
MPa	*megapascals*
MW	megawatt
NAS	National Academy of Sciences
NFPA	National Fire Protection Association
NMC&A	nuclear material control and accountability
NO_x	nitrous oxides
NRC	Nuclear Regulatory Commission
ORNL	Oak Ridge National Laboratory
ORR	Operational Readiness Review
PEIS	programmatic environmental impact statement
PIDAS	Perimeter Intrusion Detection and Assessment System
PNL	Pacific Northwest Laboratory
PAP	Personal Assurance Program
PSAP	Personal Security Assurance Program
psi	pounds per square inch
psig	pounds per square inch gauge
RCRA	Resource Conservation and Recovery Act

ROD	record of decision
SAR	Safety Analysis Report
SAS	secondary alarm station
scf	standard cubic feet
SFM	surplus fissile material
SIS	special isotope separation
SNM	special nuclear material
SPO	security police officer
SSC	safety class systems, structures, and components
SST	safe secure trailer
TBD	to be determined
TID	tamper indicating device
TPSS	two-person surveillance system
TRU	transuranic
UBC	Uniform Building Code
UCNI	Unclassified Controlled Nuclear Information
UCRL	University of California Radiation Laboratory
UPS	uninterruptible power supply
USNRC	United States Nuclear Regulatory Commission
VA	vulnerability assessment
WIPP	Waste Isolation Pilot Plant
WIPPWAC	Waste Isolation Pilot Plant Waste Acceptance Criteria